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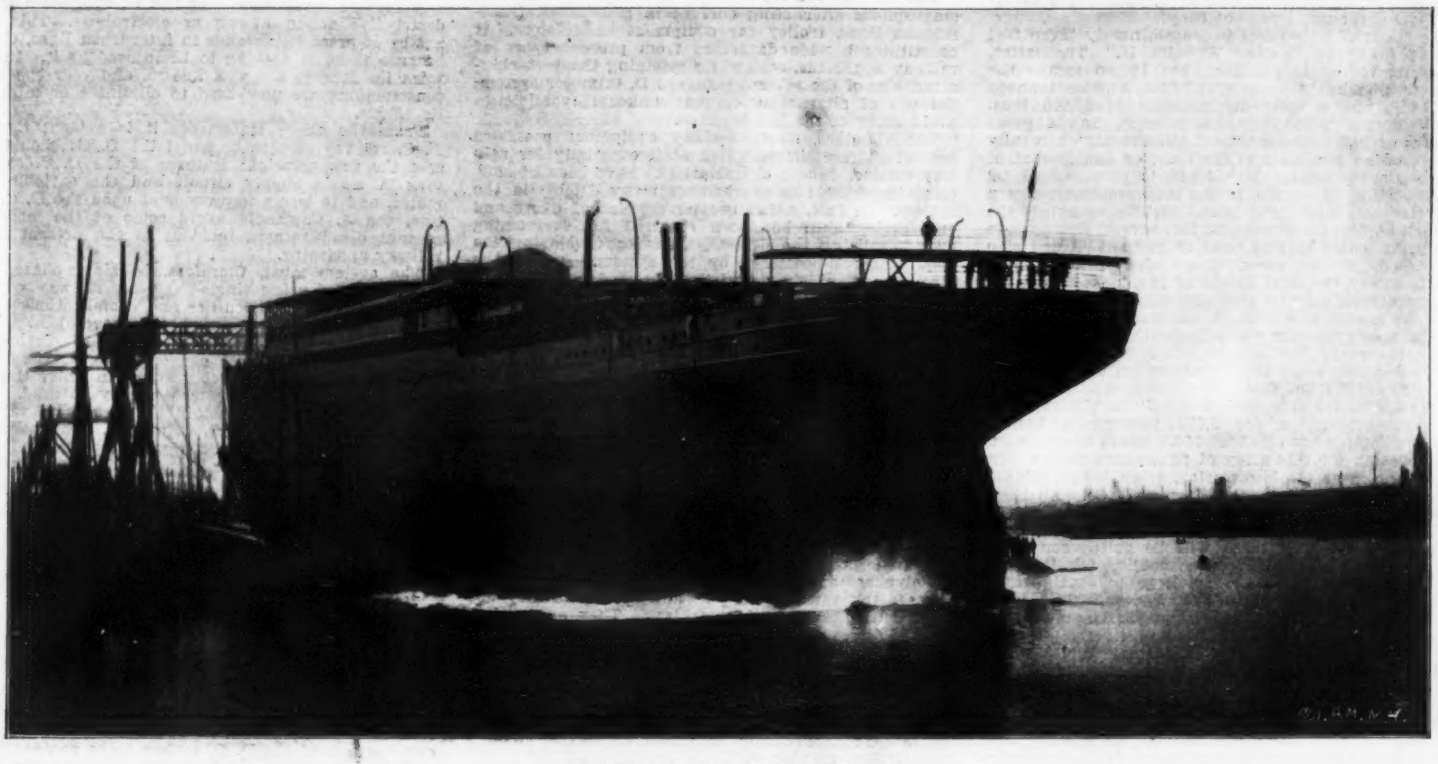

THE "CEDRIC" TAKING THE WATER.

THE "CEDRIC" READY FOR THE LAUNCH.

LAUNCH OF THE NEW TRANSATLANTIC STEAMER "CEDRIC."

THE LAUNCH OF THE WHITE STAR LINER "CEDRIC."

By Harold J. Shepstone.

The launch of the new White Star Liner "Cedric" at Belfast, Ireland, from the yards of Messrs. Harland & Wolff, on August 21 last, was an interesting event. In the first place, the new giant claims the distinction of being the largest ship ever built and the first for the Atlantic Shipping Combine. In giving her measurements it is as well, perhaps, to remember how they compare with her sister ship, the "Celtic," and also with the North German Lloyd steamer, the "Kaiser Wilhelm II.," recently launched at Stettin. Whereas the latter represents the latest type of the fast boat, the "Cedric" is an example, according to the British shipbuilder, at least, of the latest and best-paying type of liner. She is decidedly a slow boat compared to the swift liners, such as the "Deutschland" and "Kronprinz Wilhelm," but possesses much greater passenger accommodation and also capacity for carrying several thousand tons of cargo.

The "Cedric" is 700 feet in length, nearly seven feet shorter than the "Kaiser Wilhelm II." The latter, therefore, is the longer boat, but by no means the largest. She has a beam of 72 feet, a gross tonnage of 20,000, and a total displacement of 26,000 tons. The "Cedric," with her 75-foot beam, has a gross tonnage of 20,970, and a total displacement, when fully loaded, of no less than 37,870 tons, or double that of any battleship afloat. Her depth is given as 49 1-3 feet, but this, of course, is the measurement between the "structure deck" and keel. Strictly speaking, she is much higher, there being in fact several decks above this point which will be used by passengers and also by the officers and crew. Some idea of her height, that is to say the total height of the decks with their superstructure, may be gaged by comparing the vessel with the gantry under which she was constructed. It will be seen from our photographs that as she lay on the stocks ready for launching her superstructure is only a few feet below the under portion of the gantry, which is exactly 105 feet above the ground.

Like her sister ship, the "Celtic," the "Cedric" will have accommodation for 3,000 passengers, besides quarters for a crew of about 350. There is ample accommodation for this army of passengers on her nine decks, known as the lower orlop, orlop, lower, middle, upper, bridge, upper bridge, boat and sun. All these decks, too, with obvious exceptions, of course, are all real, plated decks of full length. In addition to the ordinary staterooms, there will be suites consisting of bed, sitting and bath rooms, enabling families who can afford to pay for the privilege to obtain while afloat all the privacy as well as the comforts enjoyed on shore. There will also be single berth staterooms, practically a new feature in ocean liners. Most of the staterooms boast of little adjustable tables which will no doubt be found convenient and useful. The upper rooms on the bridge deck have all square windows, which, of course, will afford much more light than that obtained from the ordinary bull's eye window.

The first-class compartments particularly are exceptionally commodious. The grand dining-saloon, situated on the upper deck, having seating capacity for over 300 persons, is an extremely handsome apartment, extending the full width of the ship, 75 feet. The smoking-room and library are also very large, the latter boasting of a number of writing tables and comfortable settees. The second-class accommodation is also excellent. The dining-saloon, smoking-room and library are very comfortable and commodious. Third-class passengers, too, have very comfortable quarters, with sitting and smoking rooms. There will be separate galleys for all three classes of passengers; also separate pantries equipped in the most approved and modern style. In the first and second-class accommodation the floors of the corridors, saloons and smoking-rooms are laid with patent rubber flooring, which not only gives a handsome appearance, but prevents slipping in rough weather and needless noise.

When the giant glided into the water and came to a standstill, she certainly did not look her size. She is built exceptionally stiff, and is made extra strong by six longitudinals built fore and aft, while increased rigidity is obtained by the use of bilge keels. The total number of steel plates in the hull is 1,392, and in the keel, double bottom, hull, and stringers there are altogether some 168,000 1¼-inch machine-driven rivets. The average length of the plates is 30 feet, some of them weighing as much as four tons. The new vessel is without question the strongest ever built.

Needless to add she is constructed on the cellular double-bottom principle, and is divided into many water-tight compartments, exceeding all official requirements in this respect. The engines are of the Harland & Wolff quadruple-expansion balanced type, having cylinders 33 inches, 47½ inches, 68½ inches and 98 inches in diameter, with 5 feet 3 inches stroke. Steam is supplied at a pressure of 210 pounds by eight double-ended boilers, each 15 feet 9 inches by 19 feet 6 inches, and will drive the monster ship at a speed of 17 knots an hour. The "Cedric's" two funnels will be oval in design. The vessel will have four masts.

Seventeen knots may seem a slow speed compared to the German flier "Kaiser Wilhelm II.," which is expected to attain a speed of about 24 knots. This vessel has a total horse power of 40,000, against the "Cedric's" 14,000. Although she only carries 1,888 passengers, most of them are first and second cabin passengers, her machinery and coal bunkers taking up so much room that there is no space left for cargo. The White Star boat, on the other hand, carries 3,000 passengers; but most of them, in contrast to the "Kaiser Wilhelm," will be steerage passengers. She has in addition room for 20,000 tons of cargo. To maintain the higher speed as much as 700 tons of coal will be consumed every twenty-four hours and a crew of 600 employed to work the ship. It is doubtful if the "Cedric" will burn more than 260 to 300 tons of coal a day, and her running expense should be less than half that of the great German flier. Again, it is a well-known fact that the German ship has cost $6,500,000 to build, whereas the "Cedric" has not cost her owners more than $4,500,000. These figures certainly go a long way to indorse the British shipowners' contention that the slower liner, with her spacious passenger accommodation and enormous cargo capacity, is the better-paying investment in the long run.

London.

WASHINGTON, BALTIMORE AND ANNAPOLIS SINGLE PHASE RAILWAY.*

By B. G. Lamme.

The Washington, Baltimore and Annapolis Railway is a new high-speed electric line extending from the suburbs of Washington to Baltimore, a distance of about 31 miles, with a branch from Annapolis Junction to Annapolis, a distance of about 15 miles. The overhead trolley will be used, and schedule speeds of over 40 miles per hour are to be attained. This road is to be the scene of the first commercial operation of an entirely new system of electric traction.

The special feature of this system is the use of single-phase alternating current in generators, transmission lines, trolley car equipment and motors. It constitutes a wide departure from present types of railway apparatus, and while retaining the best characteristics of the present standard D. C. motor system, the use of alternating current makes it possible to avoid many of the bad features.

The standard D. C. railway equipment possesses several characteristics which fit it especially for railway service. These characteristics have been of sufficient importance to overbalance many defects in the system. In fact, a far greater amount of effort and engineering skill has been required for overcoming or neutralizing the defects, than for developing the good features possessed by the system. By far the most important characteristic possessed by the D. C. system is found in the type of motor used on the car. The D. C. railway motor is in all cases a series-wound machine. The series motor is normally a variable field machine and it is this feature which has adapted the motor especially to railway service. Shunt-wound motors have been tried and abandoned. All manner of combinations of shunt, series and separate excitation have been devised and found wanting, and in many cases the real cause of failure was not recognized by those responsible for the various combinations. They all missed to a greater or less extent the variable-field feature of the straight series motor. It is true that a variable field can be obtained with shunt or separate excitation, but not without controlling or regulating devices, and the variation is not inherently automatic, as in the series motor.

Polyphase and single-phase induction motors do not possess the variable field feature at all, as they are essentially constant-field machines. They are equivalent to direct current shunt or separately excited motors, with constant field strength, which have been unable to compete successfully with the series motor. The variable field of the series motor makes it automatically adjustable for load and speed conditions. It also enables the series motor to develop large torques without proportionately increased currents. The automatically varying field is accompanied by corresponding variations in the counter E. M. F. of the armature, until the speed can adjust itself to the new field conditions. This feature is of great assistance in reducing current fluctuations, with a small number of steps in the regulating rheostat. Any increase in current, as resistance is cut out, is accompanied by a momentary increase in the counter E. M. F., thus limiting the current increase to a less value than in the case of a constant field motor.

Next to the type of motor, the greatest advantage possessed by the D. C. system lies in the use of a single current or circuit, thus permitting the use of one trolley wire. The advantages of the single trolley are so well known that it is unnecessary to discuss them. For third rail construction, the use of single current is of even greater importance than in the case of the overhead trolley. It is seen, therefore, that it is not to the direct current that credit should be given for the great success of the present railway system, but to the series type of motor and the fact that up to the present time no suitable single-phase A. C. motor has been presented.

Some of the undesirable features of the D. C. railway system should also be considered. The speed control is inefficient. A nominally constant voltage is supplied to the car, and speed control is obtained by applying variable voltage at the motor terminals. This variation is produced by the use of resistance in series with the motors, with a loss proportional to the voltage taken up by the resistance. By means of the series-parallel arrangement, the equivalent of two voltages is obtainable at the motor terminals without the use of resistance. Therefore, with series-parallel control, there are two efficient speeds with any given torque, and with multiple control there is but one efficient speed with a given torque. All other speeds are obtained through rheostatic loss, and the greater the reduction from either of the two speeds, series or parallel, the lower will be the efficiency of the equipment. At start the rheostatic losses are always relatively large, as practically all the voltage of the line is taken up in the rheostat. For heavy railroad service, where operation for long periods at other than full and half speeds may be necessary, the rheostatic loss will be a very serious matter.

The controlling devices themselves are also a source of trouble. An extraordinary amount of time and skill has been expended perfecting this apparatus. The difficulties increase with the power to be handled. The controller is a part of the equipment which is subjected to much more than ordinary mechanical wear and tear, and it can go wrong at any one of many points. The larger the equipment to be controlled, the more places are to be found in the controller which can give trouble. The best that can be said of the railway controller is that it is necessary.

Another limitation of the D. C. system is the trolley voltage. Five hundred volts is common at the car and 650 volts is very unusual. By far the larger number of the railway equipments in service to-day are unsuited for operation at 600 volts, and 700 volts in normal operation would be unsafe for practically all. The maximum permissible trolley voltage is dependent upon inherent limitations in the design of motors and controllers. The disadvantages of low voltage appear in the extra cost of copper and in the difficulty of collecting current. In heavy railroad work the current to be handled becomes enormous at usual voltages. A 2,400 horse power electric locomotive, for example, will require between 3,000 and 4,000 amperes at normal rated power and probably 6,000 to 8,000 amperes at times. With the overhead trolley these currents are too heavy to be collected in the ordinary manner, and it is a serious problem with any form of trolley or third rail system which can be used. It is evident that for heavy service, comparable with that of large steam railways, a much higher voltage than used in our present D. C. system is essential, and the use of higher voltage is destined to come, provided it is not attended by complications which more than overbalance the benefits obtained.

A further disadvantage of the D. C. system is the destructive action known as electrolysis. This may not be of great importance in interurban lines, chiefly because there is nothing to be injured by it. In city work its dangers are well known, and very expensive constructions are now used to eliminate or minimize its effects.

From the above statements it is evident that an A. C. railway system, to equal the D. C., should possess the two principal features of the D. C. system, viz.: A single supply circuit and the variable field motor, and to be an improvement upon the D. C. system, the A. C. should avoid some of the more important disadvantages incident to the present D. C. railway apparatus.

The system must, therefore, be single-phase. The importance of using single-phase for railway work is well known. The difficulties and complications of the trolley construction are such that several A. C. systems have been planned on the basis of single-phase supplied to the car, with converting apparatus on the car to transform to direct current, in order that the standard type of railway motors may be used. Such plans are attempts to obtain the two most valuable features of the present D. C. system. The polyphase railway system, used on a few European roads, employs three currents, and therefore does not meet the above requirement.

The motor for the A. C. railway service should have the variable speed characteristics of the series D. C. motor. The polyphase motor is not suitable, as it is essentially a constant field machine, and does not possess any true variable speed characteristics. Therefore it lacks both of the good features of the D. C. railway system. A new type of motor must, therefore, be furnished, as none of the alternating current motors in commercial use is adapted for the speed and torque requirements of first-class railway service. Assuming that such a motor is obtainable for operation on a single-phase circuit, the next step to consider is whether the use of alternating instead of direct current on the car, will allow some of the disadvantageous features of the D. C. system to be avoided.

The D. C. limits of voltage are at once removed, as transformers can be used for changing from any desired trolley voltage to any convenient motor voltage. Electrolysis troubles practically disappear. As transformers can be used, variations in supply voltage are easily obtainable. As the motor is assumed to have the characteristics of the direct-current series motor, speed control without rheostatic loss is practicable when voltage control is obtained. This combination, therefore, allows the motor to operate at relatively good efficiency at any speed within the range of voltage obtained. If the voltage be varied over a sufficiently wide range, the speed range may be carried from the maximum desired down to zero, and therefore, down to starting conditions. With such an arrangement no rheostat need be used under any conditions, and the lower the speed at which the motor is operated, the less the power required from the line. The least power is required at start, as the motor is doing no work and there is no rheostatic loss. The losses at start are only those in the motor and transforming apparatus, the total being less than when running at full speed with an equal torque. Such a system, therefore, permits maximum economy in power consumed by motor and control. This economy in control is not possible with the polyphase railway motor, as this motor is the equivalent of the D. C. shunt motor, with which the rheostatic loss is even greater than with the series motor.

The use of alternating current on the car allows voltage control to be obtained in several ways. In one method a transformer is arranged with a large number of leads carried to a dial or controller drum. The Stillwell regulator is a well-known example of this type of voltage control. This method of regulation is suitable for small equipments with moderate currents to be handled. The controller will be subject to some sparking, as in the case of D. C. apparatus, and therefore becomes less satisfactory as the car equipment is increased in capacity. Another method of control available with alternating current is entirely non-sparking, there being no make-and-break contacts. This controller is the so-called "induction regulator," which is a transformer with the primary and secondary windings on separate cores. The voltage in the secondary winding is varied by shifting its angular position in relation to the primary. With this type of voltage controller, very large currents can be handled, and it is especially suitable for heavy equipments, such as locomotives. It is thus seen that there is one method of control, available with alternating current, which avoids the inherent troubles of the D. C. controller. The induction regulator is primarily a transformer, and all wear and tear is confined to the supports which carry the rotor. Therefore the objectionable controller of the standard D. C. system can be eliminated, provided a suitable A. C. motor can be obtained. This ideal type of controller is not applicable to the polyphase railway motor, in which speed control can be obtained only through rheostatic loss. The polyphase control system is even more complicated than the D. C., as there must be a rheostat for each motor, and two or three circuits in

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each rheostat. It is thus apparent that by the use of single-phase alternating current with an A. C. motor having the characteristics of the D. C. series motor, the best features of the D. C. system can be obtained, and at the same time many of its disadvantages can be avoided.

This portion of the problem therefore resolves itself into the construction of a single-phase motor having the characteristics of the D. C. series motor. There are several types of single-phase A. C. motors which have the series characteristics. One type is similar in general construction to a D. C. motor, but with its magnetic circuit laminated throughout, and with such proportions that it can successfully commutate alternating current. Such a motor is a plain series motor, and can be operated on either alternating or direct current and will have the same torque characteristics in either case. Another type of motor is similar in general construction to the above, but the circuits are arranged in a different manner. The field is connected directly across the supply circuit with proper control appliances in series with it. The armature is short-circuited on itself across the brushes, and the brushes are set at an angle of approximately 45 deg. from the ordinary neutral point. The first of these two types of motors is the one best adapted for operation in large units.

This is the type of motor which is to be used on the Washington, Baltimore and Annapolis Railway. Several motors have been built and tested with very satisfactory results, both on the testing stand and under a car. The results were so favorable that the system was proposed to the Cleveland Engineering Company, representing the Washington, Baltimore and Annapolis Railway, and after investigation by their engineers it was adopted. A description of the apparatus to be used on this road will illustrate the system to good advantage.

Single-phase alternating current will be supplied to the car at a frequency of 16 2-3 cycles per second, or 2,000 alternations per minute. The current from the overhead trolley wire is normally fed in by one trolley at approximately 1,000 volts. Within the limits of the District of Columbia two trolleys are employed, as by Act of Congress the use of rails as conductors is prohibited in this district, presumably on account of electrolysis. In this case the trouble, of course, will not exist, but the contracting company has been unable to obtain permission for the grounded circuit.

The alternating current to the car is carried through a main switch or circuit breaker on the car, to an auto-transformer connected between the trolley and the return circuit. At approximately 300 volts from the ground terminal a lead is brought out from the auto-transformer and passes through the regulator to one terminal of the motors. For starting and controlling the speed an induction regulator is used with its secondary winding in series with the motors. This secondary circuit of the regulator can be made either to add to, or subtract from the transformer voltage, thus raising or lowering the voltage supplied to the motors. The regulator therefore does double duty. The controller for D. C. motors merely lowers the voltage supplied to the motors but cannot raise it, but an A. C. regulator can be connected for an intermediate voltage, and can either raise or lower the motor voltage. In this way the regulator can be made relatively small, as it handles only the variable element of the voltage and the maximum voltage in the secondary winding is but half of the total variation required.

In the equipments in question, the range of voltage at the motor is to be varied from approximately 200 volts up to 400 volts or slightly higher. The transformer on the car will supply 315 volts, and the secondary circuit of the regulator will be wound to generate slightly more than 100 volts when turned to the position of its maximum voltage. This voltage of the regulator is about one-fourth of that of the motors at full voltage. The regulator can consequently be made relatively small, in comparison with the motor capacity of the equipment. It has been found unnecessary to use much lower than 200 volts in this installation, as this allows a comparatively low running speed, and approximately 200 volts will be necessary to start with the required torque. The greater part of this voltage is necessary to overcome the E. M. F. of self-induction in the motor windings, which is dependent upon the current through the motor and is independent of the speed of the armature.

There will be four motors of 100 horse power on each car. The full rated voltage of each motor is approximately 220 volts. The motors are arranged in two pairs, each consisting of two armatures in series, and two fields in series, and the two pairs are connected in parallel. The motors are connected permanently in this manner. Since voltage control is used, there is no necessity for series parallel operation, as with D. C. motors. To insure equal voltage to the armatures in series, a balancing or equalizing action is obtained by the use of a small auto-transformer connected permanently across the two armatures in series with its middle point connected between them. The fields are arranged in two pairs, with two fields in series and two pairs in multiple. This parallels the fields independently of the armatures, which was formerly the practice with D. C. motors. It was a defective arrangement with such motors, as equal currents in the field did not insure equal field strengths in the motors, and the armatures connected in parallel therefore would be operating in fields of unequal strength, with unequal armature currents as a direct result. With alternating currents in the fields, the case is different. The voltage across the fields is dependent upon the field strengths, and the current supplied to the fields naturally divides itself for equal magnetic strengths. The chief advantage in paralleling the fields and armatures independently is, that one reversing switch may serve for the four motors and one balancing transformer may be used across the two pairs of armatures. The ordinary D. C. arrangement of armatures in series with their own fields can be used, with a greater number of switches and connections.

The induction regulator or controller resembles an induction motor in general appearance and construction. The primary winding is placed on the rotor, and the secondary or low voltage winding on the stator. The rotor also has a second winding which is permanently short-circuited on itself. The function of this short-circuited winding is to neutralize the self-induction of the secondary winding as it passes from the magnetic influence of the primary. The regulator is wound for two poles, and therefore is operated through 180 deg. in producing the full range of voltage for the motors. One end of the primary winding of the regulator is connected to the trolley, and the other to a point between the regulator and the motors. It thus receives a variable voltage as the controller is rotated. There are several advantages in this arrangement of the primary in this particular case. First, the regulator is worked at a higher induction at start, and at lower induction when running, the running position being used in these equipments for much longer periods than required for starting. Second, when the motors are operating at full voltage the current in the primary of the regulator passes through the motors but not through the auto-transformer or the secondary of the regulator. This allows considerable reduction in the size of auto-transformer and regulator.

The motors on the car are all of the straight series type. The armature and fields being connected in series, the entire current of the field passes through the armature as in ordinary series D. C. motors. The motor has eight poles, and the speed is approximately 700 revolutions at 220 volts. The general construction is similar to that of a D. C. motor, but the field core is laminated throughout, this being necessary on account of the alternating magnetic field. There are eight field-coils wound with copper strap, and all connected permanently in parallel. The parallel arrangement of field-coils assists in equalizing the field strength in the different poles, due to the balancing action of alternating circuits in parallel. This arrangement is not really necessary, but it possesses some advantages and therefore has been used. With equal magnetic strength in the poles, the magnetic pull is equalized even with the armature out of center.

The armature is similar in general construction to that of a D. C. motor. The fundamental difficulty in the operation of a commutator type of motor, on single-phase alternating current lies in the sparking at the brushes. The working current passing through the motor should be practically no more difficult to commutate than an equal direct current, and it is not this current which gives trouble. The real source of trouble is found in a local or secondary current set up in any coil, the two ends of which are momentarily short-circuited by a brush. This coil incloses the alternating magnetic field, and thus becomes a secondary circuit of which the field-coil forms the primary. In the motors of the Washington, Baltimore and Annapolis Railway, this commutation difficulty has been overcome by so constructing the motor that the secondary or short-circuit current in the armature coil is small, and the commutating conditions so nearly perfect that the combined working and secondary currents can be commutated without sparking. This condition being obtained, the motor operates like a D. C. machine and will give no more trouble at the commutator than ordinary D. C. railway motors. Experience covering a considerable period in the operation of motors of 100 horse power capacity indicates that no trouble need be feared at the commutator.

An extended series of tests were made with these motors at the Westinghouse shops at East Pittsburg, both in the testing room and under a car.

It should be noted that the efficiency is good, being very nearly equal to that of high-class D. C. motors. The power factor, as shown in these curves, is highest at light loads and decreases with the load. This is due to the fact that the power developed increases approximately in proportion to the current, while the wattless component of the input increases practically as the square of the current. The curve indicates that the average power factor will be very good. The calculations for the Washington, Baltimore and Annapolis Railway show that the average power factor of the motors will be approximately 86 per cent.

The average efficiency of these equipments will be much higher during starting and accelerating than that of corresponding D. C. equipments, as rheostatic losses are avoided. When running at normal full speed, however, the efficiency will be slightly less than with D. C. This is due to the fact that the A. C. motor efficiency is slightly lower than the D. C., and in addition there are small losses in the transformer and the regulator. The A. C. equipments are somewhat heavier than the D. C., thus requiring some extra power, both in accelerating and at full speed. Therefore, for infrequent stops the D. C. car equipment is more efficient than the A. C., but for frequent stops the A. C. shows the better efficiency. Tests on the East Pittsburg track verified this conclusion. But the better efficiency of the D. C. equipment with infrequent stops is offset with the A. C. by decreased loss in the trolley wire, by reason of the higher voltage used, and by the elimination of the rotary converter losses. The resultant efficiency for the system will therefore be equal to or better than that of the D. C.

In the Washington, Baltimore and Annapolis Railway contract the guarantee given by the Westinghouse Electric and Manufacturing Company states that the efficiency of the system shall be equal to that of the D. C. system with rotary converter substations.

There is one loss in the A. C. system which is relatively much higher than in the D. C. This is the loss in the rail return. Tests have shown that at 2,000 alternations it is three to four times as great as with an equal direct current. This would be a serious matter in cases where the D. C. rail loss is high. But the higher A. C. trolley voltage reduces the current so much that the A. C. rail loss is practically the same as with direct current at usual voltages. In many city railways the D. C. rail loss is made very low, not to lessen waste of power, but in order to reduce electrolysis. In such cases the A. C. rail loss could be higher than D. C., thus decreasing the cost of return conductors. More numerous transformer substations, with copper feeders connected to the rails at short intervals will enable the rail loss to be reduced to any extent desired.

As a frequency of 2,000 alternations per minute is used, the lighting of the cars and the substations was at first considered to be a serious difficulty, due to the very disagreeable winking of ordinary incandescent lamps at this frequency. Two methods of overcoming the winking were tried, both of which were successful. One method was by the use of split phase. A two-phase induction motor was run on a single-phase 2,000 alternating circuit, and current was taken from the unconnected primary circuit of the motor. This current was, of course, at approximately 90 deg. from the current of the supply circuit. A two-phase circuit was thus obtained on the car. Currents from the two phases were put through ordinary incandescent lamps, placed close together. The resulting illumination a few feet distant from the lamps showed about the same winking as is noticed with 3,000 alternations. With two filaments in one lamp the winking disappears entirely. A three-phase arrangement would work in the same way.

A much simpler method was tried which worked equally well. This consisted in the use of very low-voltage lamps. Low voltage at the lamp terminals allows the use of a thick filament with considerable heat inertia. Tests were made on lamps of this type at a frequency of 2,000 alternations, and the light appeared to be as steady as that from the ordinary high-frequency incandescent lamp. The low voltage is not objectionable in this case, as a number of lamps can be run in a series as in ordinary street railway practice, and any voltage desired can readily be obtained, as alternating current is used on the car.

There will be an air compressor, driven by a series A. C. motor, on each car, for supplying air to the brakes and for operating the driving mechanism of the controller. The details of this mechanism are not sufficiently near to completion to permit a description of it. The method used will be one which readily allows operation on the multiple-unit system.

The generating station contains some interesting electrical features, but there is no great departure from usual A. C. practice. There will be three 1,500 kilowatt single-phase alternators. These are 24-pole machines operating at 83 revolutions and wound for 15,000 volts at the terminals. They are of the rotating field type, with laminated magnetic circuits and field-coils of strap on edge. The field-coils are held on the pole-tips by copper supports, which serve also as dampers to assist in the parallel running. The armatures are of the usual slotted type. The armature coils are placed in partially closed slots. There are four coils per pole. The proportions of these machines are such that good inherent regulation is obtained without saturation of the magnetic circuit. The rise in potential with non-inductive load thrown off will be approximately 4 per cent. An alternative estimate was furnished for the generators proposing 20,000 volts instead of 15,000. The simplicity of the type of winding used, and the low frequency are both favorable for the use of very high voltage on the generator. As 15,000 volts was considered amply high for the service, the engineers for the railway considered it inadvisable to adopt a higher voltage.

There are to be two exciters, each of 100 kilowatts capacity at 250 revolutions. The exciters are wound for 125 volts normal. The armature of each exciter has, in addition to the commutator, two collector rings, so that single-phase alternating current can be delivered. It is the intention to use the exciters as alternators for supplying current to the system for lighting when the large generators are shut down at night.

The main station switchboard comprises three generator panels, one load panel and three feeder panels. High-tension oil-break switches are to be provided, operated by means of controlling apparatus on the panels. The switches, bus-bars and all high-tension apparatus will be in brick compartments separate from the board. In each generator circuit there are two non-automatic oil-break switches in series; and on each feeder circuit there are two overload time-limit oil-break switches in series. The two oil-break switches in series on the same circuit can be closed separately and then opened to test the switches without closing the circuit. With the switches in the closed position they are both operated at the same time by the controlling apparatus to insure opening of the circuit and to put less strain on the switches, although either one is capable of opening the load. There will be nine transformer substations distributed along the railway line. Each station will contain two 250-kilowatt oil-cooled lowering transformers, supplying approximately 1,000 volts to the trolley system. Two transformers are used in each station so that in case of accident to one transformer the station will not be entirely crippled.

It is the intention of the railway company to operate a D. C. road already equipped with the direct-current system. The present D. C. car equipments are to be retained, but the current will be supplied from a rotary converter substation fed from the main system of the Washington, Baltimore and Annapolis Railway. As this system is single-phase, it is necessary that single-phase rotaries be used in the substations. There are to be two 200-kilowatt 550-volt rotary converters. These are 4-pole, 500-revolution machines. The general construction of these machines is very similar to that of the Westinghouse polyphase rotary converters. The armature resembles that of a polyphase rotary except in the number of collector rings, and in certain details of the proportions made necessary by reason of the use of single-phase. The commutating proportions are so good that any reactions due to the use of single-phase will result in no injurious effect. The field construction is similar to that of a polyphase rotary. The laminated field-poles are provided with dampers of the "grid" or "cage" type, a form used at present in the Westinghouse polyphase rotary converters. The dampers serve to prevent hunting, as in the polyphase machines, and also to damp out pulsations due to single-phase currents in the armature. The damper acts to a certain extent as a second phase. Each rotary converter is started and brought to synchronous speed by a small series A. C. motor on the end of the shaft. The voltage at the motor termi-

nals can be adjusted either by loops from the lowering transformer or by resistance in series with the motor, so that true synchronous speed can be given to the rotary converter before throwing it on the A. C. line.

From the preceding description of this system and the apparatus used on it some conclusions may be drawn as to the various fields where it can be applied to advantage. It is evident that a good field for it will be on interurban long-distance lines such as the Washington, Baltimore and Annapolis Railway. On such railways high trolley voltage and the absence of converter substations are very important factors.

For heavy railroading also this system possesses many ideal features. It allows efficient operation of large equipments at practically any speed and any torque, and also avoids the controller troubles which are ever present with large direct current equipments. It also permits the use of high trolley voltage, thus reducing the current to be collected. In this class of service the advantages of this A. C. system are so great that it is possible that heavy railroading will prove to be the special field for it.

For general city work this system may not find a field for some time to come, as the limitations in the present system are not so great that there will be any urgent necessity for making a change. It is probable that at first it will be applied to new railways, or in changing over steam roads rather than in replacing existing city equipments. One difficulty with which the new system will have to contend is due to the fact that the A. C. equipments cannot conveniently operate on existing D. C. city lines, as is the present practice where interurban lines run into the cities. It will be preferable for it to have its own lines throughout, unless very considerable complication is permitted. When the A. C. system applied to interurban and steam railways finally becomes of predominant importance it is probable that the existing D. C. railways will gradually be changed to A. C. as a matter of convenience in tying the various lines together.

As was stated above, A. C. equipments cannot conveniently be operated on direct current lines. It does not follow, however, that the motor will not operate on direct current. On the contrary, the motor is a first-class direct-current machine, and if supplied with suitable control apparatus and proper voltage it will operate very well on the D. C. lines. This would require that the motors be connected normally in series, as the voltage per motor is low. A complete set of D. C. control apparatus would be needed when the A. C. equipment is to be run on direct current, and considerable switching apparatus would be necessary for disconnecting all the A. C. control system and connecting in the D. C. The complication of such a system may be sufficient to prevent its use, at least for some time to come.

In some cities very strict laws are in force in regard to the voltage variations in various parts of the track system. The permissible variations are so small in some cases that an enormous amount of copper is used for return conductors; and in some cases special boosters are used in the return circuits to avoid large differences of potential between the various parts of the track system. The object in limiting the conditions in this manner is to avoid troubles from electrolysis. The A. C. system will, of course, remedy this.

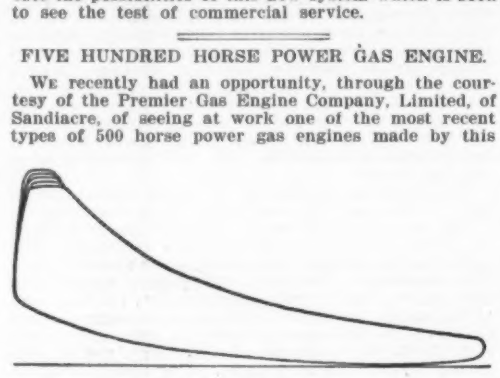
For city work it is probable that voltages of 500 or 600 would be employed instead of 1,000 or higher. The transformers and controllers can be designed to be readily changed from full to half voltage, so that low voltage can be used on one part of the line and high voltage on another. As the car equipments of such railways are usually of small capacity it is probable that speed control will be obtained by means of a transformer with a large number of leads carried out to a control drum, rather than by means of the induction regulator, as the latter device is much more expensive in small units. This is chiefly a question of cost, and if the advantages of the induction regulator are found to overweigh the objection of high first cost then it will be used even on small equipments.

In the Washington, Baltimore and Annapolis Railway the generators are wound for single-phase. In the case of large power stations with many feeders, the generators may be wound for three-phase, with single-phase circuits carried out to the transformer substation; or three-phase transmission may be used, with the transformers connected in such a manner as will give a fairly well-balanced three-phase load.

There are many arrangements and combinations of apparatus made possible by the use of alternating current in the car equipments which have not been mentioned, as it is impracticable to give a full description of all that can be done. But enough has been presented to outline the apparatus and to indicate the possibilities of this new system which is soon to see the test of commercial service.

FIVE HUNDRED HORSE POWER GAS ENGINE.

We recently had an opportunity, through the courtesy of the Premier Gas Engine Company, Limited, of Sandiacre, of seeing at work one of the most recent types of 500 horse power gas engines made by this



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firm. It was built for using with Mond producer gas, and at the time we saw it, it was running under test, with a brake on the flywheel, doing something under its full power. It was working excellently in every way, quite equaling, for evenness of turning moment, a steam engine, as far as outward indications went. We are enabled to give herewith an engraving made from a photograph taken of the engine while still in the makers' works, and from this the general design is easily seen. The bed-plate is formed of two long castings, connected together by distance pieces bolted to the ends. The cylinder bodies are bolted to the insides of these castings, and the whole forms a particularly rigid structure. Even on its temporary foundation, where it had been erected for testing purposes, the absence of anything like vibration was noticeable. The makers explain that as this engine has been designed for use with blast furnace or producer gas, it is made abnormally strong and massive, being proportioned for the highest compressions and initial pressures.

An examination of the engraving will show that it has two cylinders, which are placed tandem. The engine is of the positive scavenger type, the inclined cylinder on the top being the scavenging pump. Each explosion cylinder works on the four-stroke cycle and the explosions alternate in the cylinders, thus giving an explosion at every out stroke and a compression at each back stroke. That is to say, when one cylinder is making its explosion stroke the other is making its suction stroke; and when one is making its compression stroke the other is making its exhaust stroke. Toward the end of the exhaust stroke the admission valve is opened, and the air compressed by the scavenging pump is forced through the combustion chamber and continues to flow through while the crank turns the center. The pipe shown leading from the scavenger pump communicates with the admission valves of both cylinders. An air inlet valve admits air to this pipe, and through it to the scavenger pump, and to that explosion cylinder which happens to be making its suction stroke at any one moment. The gas is admitted through a separate valve into a mixing chamber, through which the air passes on its way to the motor cylinder. The gas valve has a variable lift, between certain limits, and hence the richness of the charge can also be varied within certain limits. Beyond these limits the gas is omitted.

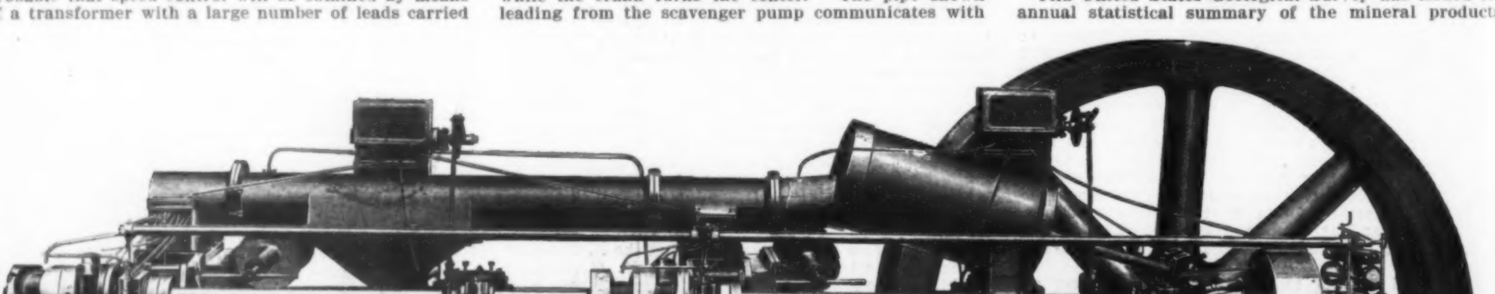
It will be noticed that a long shaft of large diameter goes from end to end of the engine. This receives its motion through worm gearing actuated by the main shaft. In the engraving this gearing is shown covered with a protection plate. The shaft performs all the motions necessary to the working of the engines. For example, the admission and exhaust valves are worked from it, and it will be noticed that the valve levers are actuated by means of cams, so that a positive opening and closing is ensured and springs are entirely done away with. The valves are placed in the cylinder covers. Both the exhaust valves and the pistons are water cooled. The method of bringing about the latter is by means of a hole bored longitudinally in the piston rod and attaching to the latter, at a place where access is made to the longitudinal hole by a cross hole, a rocking lever connected to the water supply through a hinged joint, the reciprocating motion of the piston permitting of the circulation of the water. The governor is also actuated by the horizontal shaft already mentioned as working the valves, and another smaller shaft or spindle worked by the governor controls the gas admission on the hit-and-miss principle.

The ignition is by electricity, and is in duplicate, the sparking points being so arranged that one set can be taken out, cleaned and replaced, while the engine is running at full power. This feature is the subject of a patent, as are many other points about the engine. When we saw the plant running there was a small dynamo bolted to the top of the bed-plate and driven from a pulley on the main crankshaft. This is not shown in the engraving, and, of course, any other source of electricity would be suitable. The engine is provided with a heavy flywheel carried on the main crankshaft between one of the bearings of the machine and an outside bearing carried on a pedestal. It is intended for coupling direct to a dynamo. Oiling is brought about by means of two small tanks from which pipes run to the various parts requiring oil. Pumps worked from eccentrics on the valve shafts elevate the oil into these tanks from reservoirs in the bed-plate.

We were enabled to watch this engine at work for a considerable period. The noticeable features were the smoothness of its running and the absence of noise. The finish of the various parts was also excellent, and the whole may be called a good workmanlike job. We understand that the company has already made engines similar to this for a horse power of 650, and has in hand an engine of the same type of 700 horse power, also to run with Mond gas.

The Premier Gas Engine Company has courteously forwarded us at our request an indicator diagram taken from one of the cylinders of this engine. This card was—a facsimile of which we give herewith—taken after the engine had been running at full load, and was still running fully loaded, that is to say, making one explosion per revolution. The speed was 145 revolutions per minute, and Mond gas was being used, the indicator employed being of Elliott Brothers' Simplex type.

We may add that the leading dimensions of this really fine engine are: Diameter of cylinder, 27 inches; stroke, 27 inches; diameter of flywheel, 12 feet; length over all, 27 feet. It is designed to run at a speed of from 140 to 150 revolutions per minute.—The Engineer.



FIVE HUNDRED HORSE POWER HORIZONTAL TANDEM GAS ENGINE.

UNITED STATES MINERAL PRODUCTS, 1901.

The United States Geological Survey has issued its annual statistical summary of the mineral products of the United States for the calendar year 1901. It shows for the entire country a total of \$1,092,224,380 as the value of minerals produced in 1901, as against \$1,064,408,321 in 1900. This comprises \$566,351,095 worth of non-metallic mineral products, \$524,873,284 metallic products and \$1,000,000 (estimated) of mineral products unspecified, including building and glass

sand, iron ore used as flux in lead smelting, tin ore, nitrate of soda, carbonate of soda, sulphate of soda and alumina clays used by paper manufacturers.

Following is the value of some of the various products: Pig iron, $292,174,000; silver, $77,126,382; gold, $80,218,800; copper, $86,629,266; lead, $23,280,200; zinc, $11,265,760; quicksilver, $1,382,305; aluminium, $2,238,000; antimony, $542,020; bituminous coal, $236,201,899; Pennsylvania anthracite, $112,504,045; natural gas, $27,067,500; petroleum, $66,417,335; brick clay, $13,800,000; cement, $15,788,789; stone, $55,165,576; grindstones, $580,730; borax, $1,102,110; phosphate rocks, $5,316,403; pyrites, $1,024,449; salt, $6,617,449; zinc white, $3,110,120; asphaltum, $555,335; clay, all other than brick, $2,591,332; limestone for iron flux, $4,665,836; mineral waters, $7,588,962.

ODD EFFECTS OF PHOTOGRAPHY.

In a preceding article I gave a description of an optical device designed to facilitate the photographing of small objects at a short distance by means of stereoscopic apparatus of ordinary construction, and permitting of systematically varying the degree of relief obtained. During the use of this apparatus I have often had occasion to compare, carefully and in detail, the effect produced by the direct contemplation of the object itself with that obtained by the observation of photographs of it, either by the naked eye or the stereoscope. This has permitted me frequently to remark a peculiarity that has more than once been pointed out as a defect in the graphic representation of an object by simple photography. I have therefore been led to operate under very peculiar conditions so as to produce the defect in question in a very pronounced manner.

If we simultaneously photograph objects that are geometrically similar, but of different sizes, after placing them at distances from the lens that have the same ratio to each other as have the similitude of such objects, they will all be seen by the objective under the same angle, and will therefore all be reproduced upon the sensitized plate with identical sizes. If, with the naked eye, we directly examine such a negative and have no accessory terms of comparison, we shall judge such objects, which are merely similar, to be identical in dimensions. As compared with reality, the aspect of the negative will be absolutely false.

Let us now suppose that the negative has been taken in duplicate with a stereoscopic apparatus and that we examine it in the stereoscope. Owing to the sensation of depth given by this instrument, and to the variation in the angle of convergence of the eyes we shall, when we pass from an examination of the nearest object, *A*, to the remotest one, *Z*, obtain an impression of the truth. We shall, indeed, continue to see *Z* at the same angle as *A*, but, since stereoscopic vision will make us feel that *Z* is remoter than *A*, we shall, by that very fact, judge it to be of larger dimensions. This effect is produced with such an intensity that, in order to render exact the impression made in such a case, it is not even sufficient to say that the stereoscope permits us to realize that *Z* must be larger than *A*. It is more accurate to say that it causes *Z* really to appear larger than *A*, despite the identity in the dimensions of its retinal images with those of the nearer objects.

Fig. 1 represents three bottles photographed under such conditions. These appear to be identical and arranged side by side at the same distance from the observer; and, if a person were not informed that the contrary was the case, he would not for a moment doubt the truthfulness of the labels, which attribute to all three the capacity of one liter. Nevertheless, their real capacities are, respectively, 2 liters, 1 liter, and 580 cubic centimeters. This photograph may be observed, without cutting it out of the page, by using a stereoscope. Since every one may not have a stereoscope for making such an experiment, I have annexed to Fig. 1 the Fig. 1 *a* which shows the same objects photographed by placing them this time side by side at the same distance from the apparatus. We then see them with their real relative sizes. A stereoscopic examination of Fig. 1 gives the sensation of such real ratios as perfectly as a direct examination of Fig. 1 *a* with the naked eye, but the three bottles appear then, in perspective, at different distances from the observer. Fig. 2 shows more perfectly the inaccuracy of the aspect of a photograph taken under analogous conditions. It contains two types of objects, viz., laboratory bottles and graduates. In this photograph, when examined with the naked eye, we judge the three bottles to be of identical dimensions and the three graduates to be unequal, while exactly the contrary is the case. Fig. 2 *a*, which corresponds to 2, just as 1 *a* corresponds to 1, shows such ratios of actual sizes.

Fig. 3 still further exaggerates the inaccuracy of aspect given by the plain photograph, and would make it appear that the larger of the two spheres is the one to the right, while in reality the latter has a diameter three times less than that of the one to the left. The exact ratios of such dimensions may be seen in Fig. 3 *a*. But an examination of Fig. 3 in the stereoscope shows that the larger sphere is three times farther from the observer than the smaller one.

Finally, Fig. 4 shows, with objects of a more familiar character, how very deceptive a photograph may be. It represents some mantel ornaments in which the objects, placed to the right and left of the clock, appear to be perfectly symmetrical from the viewpoint of size, and to be arranged in the same line upon the shelf. A stereoscopic examination of the negative shows that the case is entirely otherwise, and immediately reveals to the observer the fact that the dimensions in height and diameter of the candlestick to the right are greater than those of the one to the left, while the vase to the right is, as regards size, only two-thirds of that to the left. We find also that the two vases are cut out of cardboard, and that the appearance of rotundity given by the plane picture is merely an optical illusion. As a matter of fact, instead of being arranged upon the same line, these objects were placed at variable distances in depth; and the mantel shelf, in order to hold all in the position in which they were placed to be photographed, had to have a width of more than 20 inches. Fig. 4 *a* shows the same objects arranged this time in the same line, with their real relative sizes.

As a consequence of such facts, we are led to doubt, to a certain extent, the accuracy of a method generally adopted in teaching drawing, and which consists in taking the measurement of the relative distances of the various objects to be sketched by means of a pencil or ruler held with the outstretched arm. It is clear that a drawing made under such conditions, although having its perspective geometrically exact the same as a photograph, may nevertheless present a false aspect as regards reality.

I have endeavored to verify such consequences experimentally by having two draughtsmen, unapprized in advance, make drawings of some of the objects shown in Fig. 2. After stationing the first of these draughtsmen at the very spot at which the photographic apparatus was situated, I requested him to take, with outstretched arm, the measurements of the objects placed in front of him and to record the results as faithfully as possible upon paper. On the contrary, I asked the second (who naturally had not been apprized of what the first had done) to make no measurements, but to endeavor to get a correct idea of the form and dimensions of the objects by a simple examination of them at a distance, and put the results upon paper in such a way that the drawing should give the best interpretation possible of the objects themselves. The result was really the same as that given by the photographs, 2 and 2 *bis*. The drawing made from measurements was the one that gave a false notion of the real size of the objects. The conclusion of this, therefore, appears to be that when we have to draw from nature a subject in which perspective plays a very great rôle, and in which some of the objects appear in the foreground and others in very remote backgrounds, it must not be thought that we shall necessarily obtain the best possible effect by strictly recording the results given by measurements. It will be of interest to diminish the results of the measurements made in the foregrounds, and, on the contrary, to increase those made in the backgrounds. In this regard photography may be very useful to painters and draughtsmen in embarrassing cases by immediately showing whether the photographic negative, taken from the selected point of view, has a sufficiently incorrect aspect to make it expedient to apply rectifications in the direction that has just been indicated.

It is not difficult, moreover, to assure ourselves, from pictures painted by talented artists, that rectifications of this kind have been made by them, either wittingly or not, in the execution of such work.

The contradictions and inaccuracies remarked in the preceding figures finally put in evidence, with great intensity, a fact that has more than once been pointed out, and that is that "in the plane photograph the importance of the foregrounds, from the viewpoint of the dimensions of the objects that figure therein, is greatly increased to the detriment of that of the backgrounds, which is greatly diminished. Stereoscopic vision rectifies such defects and renders natural an image which, examined with the naked eye, would not be acceptable."

In any collection whatever of stereoscopic negatives, we shall find some which, seen by the naked eye, show in the foreground objects of little interest that occupy half of the total surface of the image, while the backgrounds, which contain the interesting part of the subject, pass nearly unperceived because of the too limited dimensions of their image. With the stereoscope, the aspect of such negatives is entirely transformed. The eye spontaneously neglects the foregrounds in order to seek, at the back of the negative, the interesting peculiarities of the background. This is a fact that is well known to all those who occupy themselves with stereoscopy.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from an article by E. Colardeau, in La Nature.

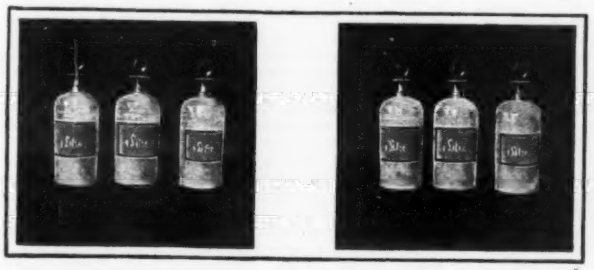


FIG. 1.—The three bottles that appear equal are really of different sizes.

FIG. 1 *a*.—The three bottles of Fig. 1 represented in their true relative sizes.

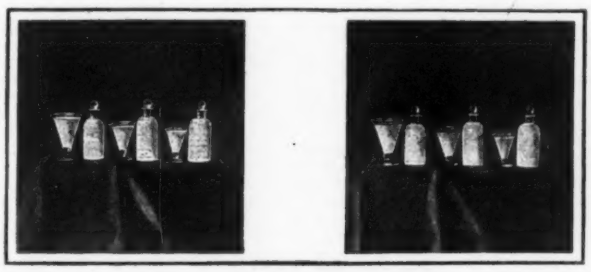


FIG. 2.—The three bottles appear to be equal, and the three graduates unequal, while precisely the opposite is the case.

FIG. 2 *a*.—The bottles and graduates of Fig. 2 represented in their true relative sizes.

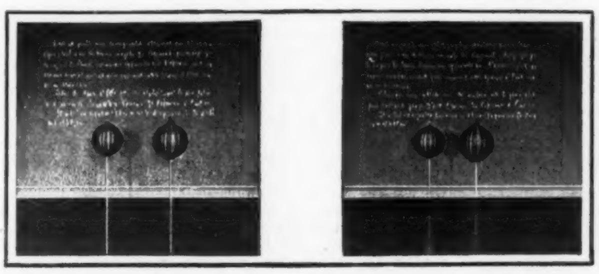


FIG. 3.—The ball on the right is apparently larger than that on the left, while in reality it is three times less in diameter.

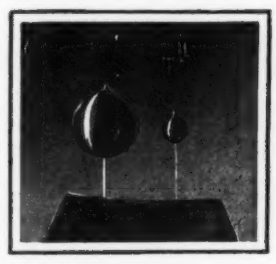


FIG. 3 *a*.—The two balls of Fig. 3 in their true relative sizes.

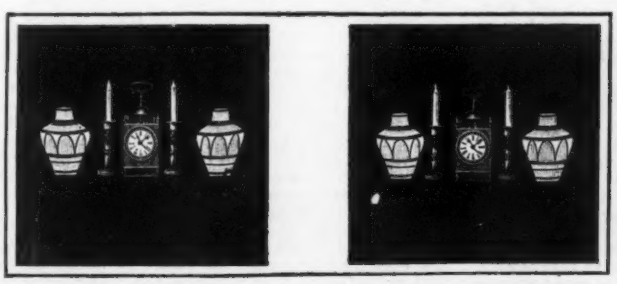


FIG. 4.—The mantel ornaments placed on the right and left of the clock appear to be of identical size, although in reality they are not.

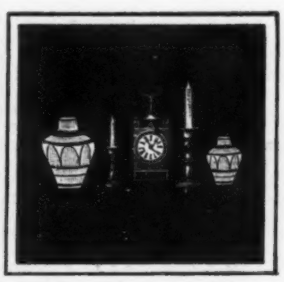


FIG. 4 *a*.—The ornaments of Fig. 4 represented in their true relative sizes.

PHOTOGRAPHS OF FALSE ASPECT.

UNTIDY STREETS AND DISEASE.

THE intelligent and well-informed portion of the community does not need to be told at this late day of the connection between dirty streets and the spread of infectious disease, but there seems to be no general appreciation of the pathogenic part that may be played by streets that are simply littered with refuse but not appearing to the eye to be dirty in the ordinary sense of the word. On this account the New York Medical

Journal thinks the New York commissioner of street cleaning, Dr. Woodbury, did well to bring the matter forcibly forward in a recent address to the Civic Club. "In two sections of this city," he said, "the people throw shoes, oilcloths, and everything else right out on the street. . . . The people don't think, and as a consequence a growing ground is afforded for the worst possible diseases. Four hundred and twelve sweepers are now on the sick report with bronchial diseases and phthisis because of the germs they have inhaled." Refuse not only serves as a nidus for morbific organisms itself, but it also very greatly obstructs the automatic cleansing that the gutters are designed to accomplish, and it increases the difficulty of the sweepers' work.

[Continued from Supplement No. 1396, page 22371.]

HISTORY OF COLD AND THE ABSOLUTE ZERO.*

By Prof. James Dewar.

It will be apparent from what has just been said that, thanks to the labors of Andrews, van der Waals, and others, theory had again far outrun experiment. We could calculate the constants and predict some of the simple physical characteristics of liquid oxygen, hydrogen or nitrogen with a high degree of confidence long before any one of the three had been obtained in the static liquid condition permitting of the experimental verification of the theory. This was the more tantalizing, because, with whatever confidence the chemist may anticipate the substantial corroboration of his theory, he also anticipates with almost equal conviction that, as he approaches more and more nearly to the zero of absolute temperature, he will encounter phenomena compelling modification, revision and refinement of formulas which fairly covered the facts previously known. Just as nearly seventy years ago chemists were waiting for some means of getting a temperature of 100 degrees below melting ice, so ten years ago they were casting about for the means of going 100 degrees lower still. The difficulty, it need hardly be said, increases in a geometrical rather than in an arithmetical ratio. Its magnitude may be estimated from the fact that to produce liquid air in the atmosphere of an ordinary laboratory is a feat analogous to the production of liquid water starting from steam at a white heat and working with all the implements and surroundings at the same high temperature. The problem was not so much how to produce intense cold as how to save it when produced from being immediately leveled up by the relatively superheated surroundings. Ordinary non-conducting packings were inadmissible because they are both cumbrous and opaque, while in working near the limits of our resources it is essential that the product should be visible and readily handled. It was while puzzling over this mechanical and manipulative difficulty in 1892 that it occurred to me that the principle of an arrangement used nearly twenty years before in some calorimetric experiments, which was based upon the work of Dulong and Petit on radiation, might be employed with advantage as well to protect old substances from heat as hot ones from rapid cooling. I therefore tried the effect of keeping liquefied gases in vessels having a double wall, the annular space between being very highly exhausted. Experiments showed that liquid air evaporated at only one-fifth of the rate prevailing when it was placed in a similar unexhausted vessel, owing to the convective transference of heat by the gas particles being enormously reduced by the high vacuum. But, in addition, these vessels lend themselves to an arrangement by which radiant heat can also be cut off. It was found that when the inner walls were coated with a bright deposit of silver the influx of heat was diminished to one-sixth the amount entering without the metallic coating. The total effect of the high vacuum and the silvering is to reduce the ingoing heat to about 3 per cent. The efficiency of such vessels depends upon getting as high a vacuum as possible, and cold is one of the best means of effecting the desired exhaustion. All that is necessary is to fill completely the space that has to be exhausted with an easily condensable vapor, and then to freeze it out in a receptacle attached to the primary vessel that can be sealed off. The advantage of this method is that no air pump is required, and that theoretically there is no limit to the degree of exhaustion that can be obtained. The action is rapid, provided liquid air is the cooling agent, and vapors like mercury, water or benzol are employed. It is obvious that when we have to deal with such an exceptionally volatile liquid as hydrogen, the vapor filling may be omitted because air itself is now an easily condensable vapor. In other words, liquid hydrogen, collected in such vessels with the annular space full of air, immediately solidifies the air and thereby surrounds itself with a high vacuum. In the same way, when it shall be possible to collect a liquid boiling on the absolute scale at about 5 degrees, as compared with the 20 degrees of hydrogen, then you might have the annular space filled with the latter gas to begin with, and yet get directly a very high vacuum, owing to the solidification of the hydrogen. Many combinations of vacuum vessels can be arranged, and the lower the temperature at which we have to operate the more useful they become. Vessels of this kind are now in general use, and in them liquid air has crossed the American continent. Of the various forms, that variety is of special importance which has a spiral tube joining the bottom part of the walls, so that any liquid gas may be drawn off from the interior of such a vessel. In the working of regenerative coils such a device becomes all-important, and such special vessels cannot be dispensed with for the liquefaction of hydrogen.

In the early experiments of Pictet and Cailletet cooling was produced by the sudden expansion of the highly compressed gas, preferably at a low temperature, the former using a jet that lasted for some time, the latter an instantaneous adiabatic expansion in a strong glass tube. Neither process was practicable as a mode of producing liquid gases, but both gave valuable indications of partial change into the liquid state by the production of a temporary mist. Linde, however, saw that the continuous use of a jet of highly compressed gas, combined with regenerative cooling, must lead to liquefaction on account of what is called the Kelvin-Joule effect; and he succeeded in making a machine, based on this principle, capable of producing liquid air for industrial purposes. These experimenters had proved that, owing to molecular attraction, compressed gases passing through a porous plug or small aperture were lowered in temperature by an amount depending on the difference of pressure, and inversely as the square of the absolute temperature. This means that for a steady difference of pressure the cooling is greater the lower the temperature. The only gas that did not show cooling under such conditions was hydrogen. Instead of being cooled it became actually hotter. The reason for this apparent anomaly in the Kelvin-Joule effect is that every gas has a thermometric point of inversion above which it is heated and below which it is cooled. This inversion point, according to van der Waals, is six and three-quarter times the critical point. The efficiency of the Linde process depends on working with highly compressed gas well below the inversion temperature, and in this respect this point may be said to take the place of the critical one, when in the ordinary way direct liquefaction is being effected by the use of specific liquid cooling agents. The success of both processes depends upon working within a certain temperature range, only the Linde method gives us a much wider range of temperature within which liquefaction can be effected. This is not the case if, instead of depending on getting cooling by the internal work done by the attraction of the gas molecules, we force the compressed gas to do external work as in the well-known air machines of Kirk and Coleman. Both these inventors have pointed out that there is no limit of temperature, short of liquefaction of the gas in use in the circuit, that such machines are not capable of giving. While it is theoretically clear that such machines ought to be capable of maintaining the lowest temperatures, and that with the least expenditure of power, it is a very different matter to overcome the practical difficulties of working such machines under the conditions. Coleman kept a machine delivering air at *minus* 83 degrees for hours, but he did not carry his experiments any further. Recently Monsieur Claude, of Paris, has, however, succeeded in working a machine of this type so efficiently that he has managed to produce one liter of liquid air per horse power expended per hour in the running of the engine. This output is twice as good as that given by the Linde machine, and there is no reason to doubt that the yield will be still further improved. It is clear, therefore, that in the immediate future the production of liquid air and hydrogen will be effected most economically by the use of machines producing cold by the expenditure of mechanical work.

LIQUID HYDROGEN AND HELIUM.

To the physicist the copious production of liquid air by the methods described was of peculiar interest and value as affording the means of attacking the far more difficult problem of the liquefaction of hydrogen, and even as encouraging the hope that liquid hydrogen might in time be employed for the liquefaction of yet more volatile elements, apart from the importance which its liquefaction must hold in the process of the steady advance toward the absolute zero. Hydrogen is an element of especial interest, because the study of its properties and chemical relations led great chemists like Faraday, Dumas, Daniel, Graham and Andrews to entertain the view that if it could ever be brought into the state of liquid or solid it would reveal metallic characters. Looking to the special chemical relations of the combined hydrogen in water, alkaline oxides, acids and salts, together with the behavior of these substances on electrolysis, we are forced to conclude that hydrogen behaves as the analogue of a metal. After the beautiful discovery of Graham that palladium can absorb some hundreds of times its own volume of hydrogen and still retain its luster and general metallic character, the impression that hydrogen was probably a member of the metallic group became very general. The only chemist who adopted another view was my distinguished predecessor, Prof. Odling. In his "Manual of Chemistry," published in 1861, he pointed out that hydrogen has chlorous as well as basic relations, and that they are as decided, important, and frequent as its other relations. From such considerations he arrived at the conclusion that hydrogen is essentially a neutral or intermediate body, and therefore we should not expect to find liquid or solid hydrogen possess the appearance of a metal. This extraordinary prevision, so characteristic of Odling, was proved to be correct some thirty-seven years after it was made. Another curious anticipation was made by Dumas in a letter addressed to Pictet, in which he says that the metal most analogous to hydrogen is magnesium and that probably both elements have the same atomic volume, so that the density of hydrogen, for this reason, would be about the value elicited by subsequent experiments. Later on, in 1872, when Newlands began to arrange the elements in periodic groups, he regarded hydrogen as the lowest member of the chlorine family; but Mendeléeff in his later classification placed hydrogen in the group of the alkaline metals; on the other hand, Dr. Johnstone Stoney classes hydrogen with the alkaline earth metals and magnesium. From this speculative divergency it is clear no definite conclusion could be reached regarding the physical properties of liquid or solid hydrogen, and the only way to arrive at the truth was to prosecute low-temperature research until success attended the efforts to produce its liquefaction. This result I definitely obtained in 1898. The case of liquid hydrogen is, in fact, an excellent illustration of the truth already referred to, that no theoretical forecast, however apparently justified by analogy, can be finally accepted as true until confirmed by actual experiment. Liquid hydrogen is a colorless, transparent body of extraordinary intrinsic interest. It has a clearly defined surface, is easily seen, drops well, in spite of the fact that its surface tension is only the thirty-fifth part of that of water, or about one-fifth that of liquid air, and can be poured easily from vessel to vessel. The liquid does not conduct electricity, and, if anything, is slightly diamagnetic. Compared with an equal volume of liquid air, it requires only one-fifth the quantity of heat for vaporization; on the other hand, its specific heat is ten times that of liquid air or five times that of water. The coefficient of expansion of the fluid is remarkable, being about ten times that of gas; it is by far the lightest liquid known to exist, its density being only one-fourteenth that of water; the lightest liquid previously known was liquid marsh gas, which is six times heavier. The only solid which has so small density as to float upon its surface is a piece of pith wood. It is by far the coldest liquid known. At ordinary atmospheric pressure it boils at *minus* 252.5 degrees or 20.5 degrees absolute. The critical point of the liquid is about 29 degrees absolute and the critical pressure not more than fifteen atmospheres. The vapor of the hydrogen arising from the liquid has nearly the density of air—that is, it is fourteen times that of the gas at the ordinary temperature. Reduction of the pressure by an air pump brings down the temperature to *minus* 258 degrees, when the liquid becomes a solid resembling frozen foam, and this by further exhaustion is cooled to *minus* 260 degrees, or 13 degrees absolute, which is the lowest steady temperature that has been reached. The solid may also be got in the form of a clear, transparent ice, melting at about 15 degrees absolute, under a pressure of 55 millimeters, possessing the unique density of one-eleventh that of water. Such cold involves the solidification of every gaseous substance but one that is at present definitely known to the chemist, and so liquid hydrogen introduces the investigator to a world of solid bodies. The contrast between this refrigerating substance and liquid air is most remarkable. On the removal of the loose plug of cotton-wool used to cover the mouth of the vacuum vessel in which it is stored, the action is followed by a miniature snowstorm of solid air, formed by the freezing of the atmosphere at the point where it comes into contact with the cold vapor rising from the liquid. This solid air falls into the vessel and accumulates as a white snow at the bottom of the liquid hydrogen. When the outside of an ordinary test tube is cooled by immersion in the liquid, it is soon observed to fill up with solid air, and if the tube be now lifted out a double effect is visible, for liquid air is produced both in the inside and on the outside of the tube—in the one case by the melting of the solid, and in the other by condensation from the atmosphere. A tuft of cotton-wool soaked in the liquid and then held near the pole of a strong magnet is attracted, and it might be inferred therefrom that liquid hydrogen is a magnetic body. This, however, is not the case: the attraction is due neither to the cotton-wool nor to the hydrogen—which indeed evaporates almost as soon as the tuft is taken out of the liquid—but to the oxygen of the air, which is well known to be a magnetic body, frozen in the wool by the extreme cold.

The strong condensing powers of liquid hydrogen afford a simple means of producing vacua of very high tenuity. When one end of a sealed tube containing ordinary air is placed for a short time in the liquid, the contained air accumulates as a solid at the bottom, while the higher part is almost entirely deprived of particles of gas. So perfect is the vacuum thus formed that the electric discharge can be made to pass only with the greatest difficulty. Another important application of liquid air, liquid hydrogen, etc., is as analytic agents. Thus, if a gaseous mixture be cooled by means of liquid oxygen, only those constituents will be left in the gaseous state which are less condensable than oxygen. Similarly, if this gaseous residue be in its turn cooled in liquid hydrogen, a still further separation will be effected, everything that is less volatile than hydrogen being condensed to a liquid or solid. By proceeding in this fashion it has been found possible to isolate helium from a mixture in which it is present to the extent of only one part in one thousand. By the evaporation of solid hydrogen under the air pump we can reach within 13 or 14 degrees of the zero, but there or thereabouts our progress is barred. This gap of 13 degrees might seem at first sight insignificant in comparison with the hundreds that have already been conquered. But to win one degree low down the scale is quite a different matter from doing so at higher temperatures; in fact, to annihilate these few remaining degrees would be a far greater achievement than any so far accomplished in low-temperature research. For the difficulty is twofold, having to do partly with process and partly with material. The application of the methods used in the liquefaction of gases becomes continually harder and more troublesome as the working temperature is reduced; thus, to pass from liquid air to liquid hydrogen—a difference of 60 degrees—is, from a thermodynamic point of view, as difficult as to bridge the gap of 150 degrees that separates liquid chloride and liquid air. By the use of a new liquid gas exceeding hydrogen in volatility to the same extent as hydrogen does nitrogen, the investigator might get to within five degrees of the zero; but even a second hypothetical substance, again exceeding the first one in volatility to an equal extent, would not suffice to bring him quite to the point of his ambition. That the zero will ever be reached by man is extremely improbable. A thermometer introduced into regions outside the uttermost confines of the earth's atmosphere might approach the absolute zero, provided that its parts were highly transparent to all kinds of radiation, otherwise it would be affected by the radiation of the sun, and would therefore become heated. But supposing all difficulties to be overcome, and the experimenter to be able to reach within a few degrees of the zero, it is by no means certain that he would find the near approach of the death of matter sometimes pictured. Any forecast of the phenomena that would be seen must be based on the assumption that there is continuity between the processes studied at attainable temperatures and those which take place at still lower ones. Is such an assumption justified? It is true that many changes in the properties of substances have been found to vary steadily with the degree of cold to which they are exposed. But it would be rash to take for granted that the changes which have been traced in explored regions continue to the same extent and in the same direction in those which are as yet unex-

* Abstract of a Presidential Address delivered at the Belfast meeting on September 10, 1902, of the British Association for the Advancement of Science.

plored. Of such a breakdown low-temperature research has already yielded a direct proof at least in one case. A series of experiments with pure metals showed that their electrical resistance gradually decreases as they are cooled to lower and lower temperatures, in such ratio that it appeared probable that at the zero of absolute temperature they would have no resistance at all and would become perfect conductors of electricity. This was the inference that seemed justifiable by observations taken at depths of cold which can be obtained by means of liquid air and less powerful refrigerants. But with the advent of the more powerful refrigerant liquid hydrogen it became necessary to revise that conclusion. A discrepancy was first observed when a platinum resistance thermometer was used to ascertain the temperature of that liquid boiling under atmospheric and reduced pressure. All known liquids, when forced to evaporate quickly by being placed in the exhausted receiver of an air pump, undergo a reduction in temperature, but when hydrogen was treated in this way it appeared to be an exception. The resistance thermometer showed no reduction as was expected, and it became a question whether it was the hydrogen or the thermometer that was behaving abnormally. Ultimately, by the adoption of other thermometrical appliances, the temperature of the hydrogen was proved to be lowered by exhaustion as theory indicated. Hence it was the platinum thermometer which had broken down; in other words, the electrical resistance of the metal employed in its construction was not, at temperatures about *minus* 250 deg. C., decreased by cold in the same proportion as at temperatures about *minus* 200 deg. This being the case, there is no longer any reason to suppose that at the absolute zero platinum would become a perfect conductor of electricity; and in view of the similarity between the behavior of platinum and that of other pure metals in respect of temperature and conductivity, the presumption is that the same is true of them also. At any rate the knowledge that in the case of at least one property of matter we have succeeded in attaining a depth of cold sufficient to bring about unexpected change in the law expressing the variation of that property with temperature, is sufficient to show the necessity for extreme caution in extending our inferences regarding the properties of matter near the zero of temperature. Lord Kelvin evidently anticipates the possibility of more remarkable electrical properties being met with in the metals near the zero. A theoretical investigation on the relation of "electrons" and atoms has led him to suggest a hypothetical metal having the following remarkable properties: below 1 degree absolute it is a perfect insulator of electricity, at 2 degrees it shows noticeable conductivity, and at 6 degrees it possesses high conductivity. It may safely be predicted that liquid hydrogen will be the means by which many obscure problems of physics and chemistry will ultimately be solved, so that the liquefaction of the last of the old permanent gases is as pregnant now with future consequences of great scientific moment as was the liquefaction of chlorine in the early years of the last century.

The next step toward the absolute zero is to find another gas more volatile than hydrogen, and that we possess in the gas occurring in cleveite, identified by Ramsay as helium, a gas which is widely distributed, like hydrogen, in the sun, stars and nebulæ. A specimen of this gas was subjected by Olszewski to liquid air temperatures, combined with compression and subsequent expansion, following the Cailletet method, and resulted in his being unable to discover any appearance of liquefaction, even in the form of mist. His experiments led him to infer that the boiling point of the substance is probably below 9 degrees absolute. After Lord Rayleigh had found a new source of helium in the gases which are derived from the Bath springs, and liquid hydrogen became available as a cooling agent, a specimen of helium cooled in liquid hydrogen showed the formation of fluid, but this turned out to be owing to the presence of an unknown admixture of other gases. As a matter of fact, a year before the date of this experiment I had recorded indications of the presence of unknown gases in the spectrum of helium derived from this source. When subsequently such condensable constituents were removed, the purified helium showed no signs of liquefaction, even when compressed to 80 atmospheres, while the tube containing it was surrounded with solid hydrogen. Further, on suddenly expanding, no instantaneous mist appeared. Thus helium was definitely proved to be a much more volatile substance than hydrogen in either the liquid or solid condition. The inference to be drawn from the adiabatic expansion effected under the circumstances is that helium must have touched a temperature of from 9 to 10 degrees for a short time without showing any signs of liquefaction, and consequently that the critical point must be still lower. This would force us to anticipate that the boiling point of the liquid will be about 5 degrees absolute, or liquid helium will be four times more volatile than liquid hydrogen, just as liquid hydrogen is four times more volatile than liquid air. Although the liquefaction of the gas is a problem for the future, this does not prevent us from safely anticipating some of the properties of the fluid body. It would be twice as dense as liquid hydrogen, with a critical pressure of only 4 or 5 atmospheres. The liquid would possess a very feeble surface-tension, and its compressibility and expansibility would be about four times that of liquid hydrogen, while the heat required to vaporize the molecule would be about one-fourth that of liquid hydrogen. Heating the liquid 1 degree above its boiling point would raise the pressure by $1\frac{3}{4}$ atmospheres, which is more than four times the increment for liquid hydrogen. The liquid would be only seventeen times denser than its vapor, whereas liquid hydrogen is sixty-five times denser than the gas it gives off. Only some 3 or 4 degrees would separate the critical temperature from the boiling point and the melting point, whereas in liquid hydrogen the separation is respectively 10 and 15 degrees. As the liquid refractivities for oxygen, nitrogen and hydrogen are closely proportional to the gaseous values, and as Lord Rayleigh has shown that helium has only one-fourth the refractivity of hydrogen, although it is twice as dense, we must infer that the refractivity of liquid helium would also be about one-fourth that of liquid hydrogen. Now hydrogen has the smallest refractivity of any known liquid, and yet liquid helium will have only about one-fourth of this value—comparable, in fact, with liquid hydrogen just below its critical point. This means that the liquid will be quite exceptional in its optical properties, and very difficult to see. This may be the explanation of why no mist has been seen on its adiabatic expansion from the lowest temperatures. Taking all these remarkable properties of the liquid into consideration, one is afraid to predict that we are at present able to cope with the difficulties involved in its production and collection. Provided the critical point is, however, not below 8 degrees absolute, then from the knowledge of the conditions that are successful in producing a change of state in hydrogen through the use of liquid air, we may safely predict that helium can be liquefied by following similar methods. If, however, the critical point is as low as 6 degrees absolute, then it would be almost hopeless to anticipate success by adopting the process that works so well with hydrogen. The present anticipation is that the gas will succumb after being subjected to this process, only, instead of liquid air under exhaustion being used as the primary cooling agent, liquid hydrogen evaporating under similar circumstances must be employed. In this case, the resulting liquid would require to be collected in a vacuum vessel the outer walls of which are immersed in liquid hydrogen. The practical difficulties and the cost of the operation will be very great; but, on the other hand, the descent to a temperature within 5 degrees of the zero would open out new vistas of scientific inquiry, which would add immensely to our knowledge of the properties of matter. To command in our laboratories a temperature which would be equivalent to that which a comet might reach at an infinite distance from the sun would indeed be a great triumph for science. If the present Royal Institution attack on helium fail, then we must ultimately succeed by adopting a process based on the mechanical production of cold through the performance of external work. When a turbine can be worked by compressed helium, the whole of the mechanism and circuits being kept surrounded with liquid hydrogen, then we need hardly doubt that the liquefaction will be effected. In all probability gases other than helium will be discovered of greater volatility than hydrogen. It was at the British Association Meeting in 1896 that I made the first suggestion of the probable existence of an unknown element which would be found to fill up the gap between argon and helium, and this anticipation was soon taken up by others and ultimately confirmed. Later, in the Bakerian Lecture for 1901, I was led to infer that another member of the helium group might exist having the atomic weight about 2, and this would give us a gas still more volatile, with which the absolute zero might be still more nearly approached. It is to be hoped that some such element or elements may yet be isolated and identified as coronium or nebulium. If among the unknown gases possessing a very low critical point some have a high critical pressure instead of a low one, which ordinary experience would lead us to anticipate, then such difficultly liquefiable gases would produce fluids having different physical properties from any of those with which we are acquainted. Again, gases may exist having smaller atomic weights and densities than hydrogen, yet all such gases must, according to our present views of the gaseous state, be capable of liquefaction before the zero of temperature is reached. The chemists of the future will find ample scope for investigation within the apparently limited range of temperature which separates solid hydrogen from zero. Indeed, great as is the sentimental interest attached to the liquefaction of these refractory gases, the importance of the achievement lies rather in the fact that it opens out new fields of research and enormously widens the horizon of physical science, enabling the natural philosopher to study the properties and behavior of matter under entirely novel conditions. This department of inquiry is as yet only in its infancy, but speedy and extensive developments may be looked for, since within recent years several special cryogenic laboratories have been established for the prosecution of such researches, and a liquid-air plant is becoming a common adjunct to the equipment of the ordinary laboratory.

THE UPPER AIR AND AURORAS.

The present liquid ocean, neglecting everything for the moment but the water, was at a previous period of the earth's history part of the atmosphere, and its condensation has been brought about by the gradual cooling of the earth's surface. This resulting ocean is subjected to the pressure of the remaining uncondensed gases, and as these are slightly soluble they dissolve to some extent in the fluid. The gases in solution can be taken out by distillation or by exhausting the water, and if we compare their volume with the volume of water as steam, we should find about 1 volume of air in 60,000 volumes of steam. This would then be about the rough proportion of the relatively permanent gas to condensable gas which existed in the case of the vaporized ocean. Now let us assume the surface of the earth gradually cooled to some 200 degrees below the freezing point; then, after all the present ocean was frozen, and the climate became three times more intense than any Arctic frost, a new ocean of liquid air would appear, covering the entire surface of the frozen globe about thirty-five feet deep. We may now apply the same reasoning to the liquid air ocean that we formerly did to the water one, and this would lead us to anticipate that it might contain in solution some gases that may be far less condensable than the chief constituents of the fluid. In order to separate them we must imitate the method of taking the gases out of water. Assume a sample of liquid air cooled to the low temperature that can be reached by its own evaporation, connected by a pipe to a condenser cooled in liquid hydrogen; then any volatile gases present in solution will distill over with the first portions of the air, and can be pumped off, being uncondensable at the temperature of the condenser. In this way, a gas mixture, containing, of the known gases, free hydrogen, helium and neon, has been separated from liquid air. It is interesting to note in passing that the relative volatilities of water and oxygen are in the same ratio as those of liquid air and hydrogen, so that the analogy between the ocean of water and that of liquid air has another suggestive parallel. The total uncondensable gas separated in this way amounts to about one fifty-thousandth of the volume of the air, which is about the same proportion as the air dissolved in water. That free hydrogen exists in air in small amount is conclusively proved, but the actual proportion found by the process is very much smaller than Gautier has estimated by the combustion method. The recent experiments of Lord Rayleigh show that Gautier, who estimated the hydrogen present as one five-thousandth, has in some way produced more hydrogen than he can manage to extract from pure air by a repetition of the same process. The spectroscopic examination of these gases throws new light upon the question of the aurora and the nature of the upper air. On passing electric discharges through the tubes containing the most volatile of the atmospheric gases, they glow with a bright orange light, which is especially marked at the negative pole. The spectroscope shows that this light consists, in the visible part of the spectrum, chiefly of a succession of strong rays in the red, orange and yellow, attributed to hydrogen, helium and neon. Besides these, a vast number of rays, generally less brilliant, are distributed through the whole length of the visible spectrum. The greater part of these rays are of, as yet, unknown origin. The violet and ultra-violet part of the spectrum rivals in strength that of the red and yellow rays. As these gases probably include some of the gases that pervade interplanetary space, search was made for the prominent nebular, coronal and auroral lines. No definite lines agreeing with the nebular spectrum could be found, but many lines occurred closely coincident with the coronal and auroral spectrum. But before discussing the spectroscopic problem it will be necessary to consider the nature and condition of the upper air.

(To be continued.)

ON THE ATOMIC WEIGHT OF RADIUM.

By MDME. CURIE.

By concentrating by fractional crystallization the greater part of the radiferous barium at my disposal I have succeeded in obtaining about one decigramme of perfectly pure radium chloride. This has enabled me to determine the atomic weight of radium.

It results from the following experiments that the atomic weight of radium is 225 (taking $Cl = 35.4$ and $Ag = 107.8$) with a probable uncertainty of not more than one unit, radium being considered a bivalent element.

The method employed consists of estimating, in the state of chloride of silver, the chlorine contained in a known weight of anhydrous radium chloride. As a control experiment I determined the atomic weight of barium by the same method, under the same conditions, and with the same quantity of material. The numbers found always fell between 137 and 138. I have also found that this method gives satisfactory results even with a very small quantity of material.

Many determinations were made with radium chloride; after each operation the radium was brought to the state of chloride in the following manner: The liquid, containing after the estimation radium nitrate and silver nitrate in excess, was mixed with pure hydrochloric acid. The silver chloride was separated by filtration, and the filtrate was evaporated to dryness several times with an excess of pure hydrochloric acid. Experience shows that all the nitric acid may be eliminated in this way.

The weighings were performed on an aperiodic Curie balance in perfect adjustment, and weighing to the twentieth of a milligramme. This direct reading balance permits of very rapid weighings, an essential condition for weighing the anhydrous chlorides of barium and radium, which slowly absorb water in spite of the presence of desiccating agents in the balance. The substance to be weighed is placed in a platinum crucible; this crucible has been in use a long time, and I have verified that its weight does not vary a tenth of a milligramme in the course of an operation.

The hydrated chloride obtained by crystallization was heated in an oven to transform it into the anhydrous chloride. Experience shows that when the chloride was kept for some hours at 100 deg. its weight does not alter, even when the temperature rises to 200 deg. and is kept there for some hours. Therefore the anhydrous chloride so obtained constitutes a perfectly definite body. In all the estimates the chloride was dried at 150 deg.

M. Demarcay has been good enough to examine the spectrum of the radium chloride submitted to analysis, and has given me valuable indications of the degree of purity of the body.

Two series of experiments were made. The first was with a radium chloride which M. Demarcay considered sensibly pure, but in which the spectrum showed still the three principal lines of barium with good intensity. The numbers obtained in four successive operations were the following:

220.7	223.0	222.8	223.1

I then undertook a new purification, and succeeded in obtaining a product much more pure. M. Demarcay considers that this second product only contains a minimum quantity of barium incapable of influencing appreciably the atomic weight.

Here are the results of three determinations made with this perfectly pure radium:

225.3	225.8	224.0

The mean of these numbers is 225.0. I think this number is within one unit of the truth.

The silver chloride from the estimations was always radio-active and luminous. I satisfied myself that it had not carried down a ponderable quantity of radium. I have found also that the weight of radium chloride regenerated did not vary in the operations.

The separation of the radium chloride was effected by fractionally crystallizing in a hydrochloric solution a radiferous barium chloride which already had been purified carefully. When the concentration of radium becomes of a certain strength the crystals, at first colorless in the mother-liquor, become yellow or rose colored a few hours after their deposition. This

coloration disappears on solution. It appears to be due to the simultaneous presence of barium and radium, for crystals of pure radium chloride do not become colored. This observation may be useful for following the course of the fractionation.

Pure anhydrous radium chloride is spontaneously luminous.

From its chemical properties radium is an element of the alkaline-earthy series, and in this series it is the higher homologue of barium. According to its atomic weight it should be placed in Mendeleeff's table below barium in the alkaline-earthy series, and on the line with thorium and uranium.—Comptes Rendus.

A NOVEL AUTOMOBILE FORE-CARRIAGE.

Among automobile novelties of the first rank for the year 1902 are the fore-carriages of the Society des Transformateurs Automobile Riegel, which passed unnoticed by many of the visitors at the Paris show, among the innumerable varieties of motors which have so many general points of resemblance that a motor with original and novel details of construction not visible to the general observer, was overlooked.

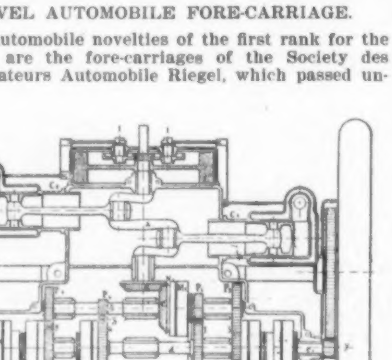


Fig. 1.—DIAGRAM OF MECHANISM OF RIEGEL FORE-CARRIAGE.

In constructing its fore-carriage this company makes use of electro-magnetic clutches, which are inclosed like gears and placed on the right and left sides of the fore-carriage. This form of clutch for vehicles has been recently perfected by M. Riegel after much patient study, and although the employment of inclosed electro-magnets in place of gears dates back more than fifty years, and although the credit of having originated the use of them for this purpose belongs to an English physicist, Weber, the French engineer, Achard, was the first to make practical application of this kind of clutch. After France seemed to lose interest in the question, and after various and interrupted attempts at using this form of clutch had been made in the United States, the development of automobilism in the former country caused several constructors to again attempt making use of it.

The Riegel company, as one can see from the following description, has made very general use of this method of control, and in so doing has applied it in several original ways.

While on the one hand this fore-carriage plays the role of a transformer, and changes large carriages, delivery wagons and the like to motor machines, on the other hand it is also found on ordinary automobiles with a divided driving axle, to which machines it contributes extraordinary facility of steering and operation which results from the employment of electro-magnetic clutches. We shall describe successively these two kinds of fore-carriages made by the Riegel company.

The problem of the transformation of horse-drawn carriages is not a new one, and, if it has already been solved in a masterly manner for heavy-weight vehicles, by the de Dion steam tractors, it has not been so solved for vehicles de luxe, or delivery wagons, where, on account of reasons of appearance with the former and reasons of convenience with the latter, it is not possible to transform a four-wheeled vehicle into a six-wheeled one in which the four front wheels act as a tractor.

A number of attempts have been made to do this, however, and our readers are doubtless familiar with them. If success—pecuniary at least—has not crowned the efforts of these inventors, certain of whom have proved themselves possessed of patience and ingenuity worthy of praise, the reason is that the problem contains such formidable difficulties when one comes to examine it closely, that one finds himself questioning immediately whether it is capable of solution at all.

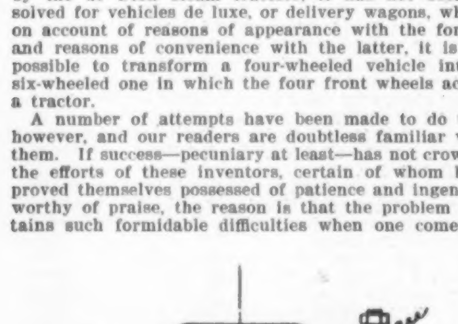


Fig. 2.—DIAGRAM OF STEERING LEVER.

The first difficulty to be encountered is the fragility of the usual horse-drawn carriage. It is only necessary to conjure up in one's mind a picture of the gracious-appearing cradle of luxury of "my lord" or note the thickness of the slim band that connects the body of a coupé with the driver's seat, to fear ruptures in such relatively weak parts.

Any motive system applicable to such vehicles which produces sudden jerks when the gear is thrown in or the speed changes effected, would condemn the carriage when worked hard, and if there was not a rupture of the weak part the varnish would certainly be found to crack at the panels and the panels themselves to become dislocated.

But this would not be all. Admitting the total suppression of all such jerks, the fact would still remain that the pull of the motor at the front must be transmitted through the body to the back of the vehicle in overcoming the resistance to traction of said body. In like manner the pull of the horse is exerted, it is true, but it should be noted that as the speed of the vehicle must be increased from seven or eight miles an hour (the speed of the horse) to from twelve to eighteen miles an hour (the maximum speed allowable without displaying large numbers), this increase of speed will exert a greater tractive strain on the body, which it may be incapable of withstanding. The transmission of the tractive pull from the front to the rear should therefore be made not through the body, but through an auxiliary metal frame.

In the Riegel system the suppression of jerks is obtained so absolutely that if one did not see the hands of the driver it would be impossible to tell, from physical sensation experienced in the vehicle, the precise moment when the speed was changed. This easy motion of acceleration is obtained by the magnetic clutches, which are so regulated as not to take hold until there has been a certain amount of slipping—an amount fixed in each case by the constructor, after the owner of the vehicle has determined its total weight.

The transmission of the tractive pull from the fore-carriage to the rear axle is through a double frame of drawn steel tubing. Taken as a whole, the fore-carriage, the steel connecting tube and the back axle, form a rigid frame on which the carriage body is simply an accessory.

In cases of this kind observation is worth more than affirmation, and one has only to see the elegant vehicles of a master hand, traveling rapidly by without a joint of varnish cracked, thanks to the Riegel system, to be greatly edified.

The second capital objection relative to the transformation of horse-drawn vehicles lies in the construction of the fore-carriage motor.

In this instance the motor that propels the two driving wheels is a gasoline one of the horizontal two-cylinder type. The operator must necessarily have conveniently at hand all the controlling apparatus. In the various fore-carriages heretofore constructed this apparatus has consisted of mechanical levers, the proper movement of which was impeded by difficulties of operation, such as a movement of rotation on the one hand and the incessant jolting from the irregularities of the road on the other.

Fig. 3.—STEERING COLUMN AND FRAME.

With all other fore-carriages as much depends on the vehicle itself as on the arrangement of its parts and it would not be possible, on account of the mechanical transmission, to transform any vehicle with the same fore-carriage, or to use the latter regularly on more than one vehicle.

But in the Riegel fore-carriage all the mechanical transmission parts—sliding speed-change gears, differential, etc.—have been done away with, and in their place has been substituted a bundle of wires, through which the vehicle is controlled. These wires, by their very nature, are unaffected by shocks or jars or by changes in direction of the front with respect to the back of the vehicle. For the same reason, the vehicle can be of any kind or form. The steering and controlling column that goes on the front is always the same, as well as the fore-carriage itself, and the wires that make the connection.

The mechanism of the fore-carriage consists in the first place of a horizontal, double, opposed cylinder motor, set crosswise of the vehicle, and having its shaft *a* connected through bevel gears, *c c'*, to a countershaft, *b*. This countershaft carries four gears, P_1, P_2, P_3, P_4, all of which mesh with similar gears on the driving shaft, *d*, and are, with the exception of P_1, keyed on *b*. The corresponding gears, 1, 2, 3, 4, on shaft *d*, are, with the exception of 1 (which is keyed on *d*), loose on the shaft and fastened to smooth metal disks, N_2, N_3, N_4, of magnetic material, adapted to be strongly attracted by the electro-magnets, M_2, M_3, M_4, which are keyed to the shaft. In the case of the first pair of gears, P_1, 1, the former is fastened to the electro-magnet, M_1, which is loose on shaft *b* and intended to attract disk *N*, keyed on said shaft, while the latter is keyed on shaft *d*. This arrangement is just the reverse of that of the other pairs of gears.

The electro-magnets are of the usual form and are inclosed in a casing with smooth surface adapted to attract and hold the respective disks, *N*, when the current is applied through the insulated brush and collecting ring.

The gasoline motor is started by a crank and drives the countershaft, *b*, but the driving shaft, *d*, remains stationary, since for all the four pairs of gears, one member of each is loose on its shaft.

If the operator sends current through the first speed electro-magnet, this magnet, M_1, which is loose on the shaft and has attached to it the gear, P_1, attracts the disk N_1, which is fastened to the bevel gear, *C'*. Thus P is locked to shaft *b* and drives gear 1 and shaft *d*, on which the latter is keyed.

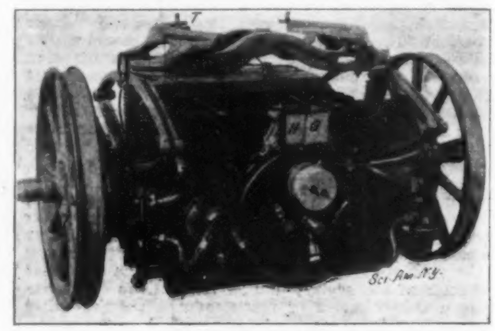


Fig. 4.—FRONT VIEW OF FORE-CARRIAGE.

Upon moving his controller to the second contact, the driver cuts the current off from M_1 and sends it through M_2, which is keyed on shaft *d*. This shaft is then driven at the second speed by gears P_2, 2. The third speed and reverse are obtained in like manner; the latter being accomplished by means of an intermediate pinion.

We will now consider the steering, which is quite ingenious and is accomplished without the use of a differential gear. If the driving pinions, *x* and *y*, on shaft *d*, which are always in mesh with the large gears fastened to the wheels, were left continually fastened to *d*, the carriage could travel only in a straight line. Consequently the ends of shaft *d*, on which these pinions are mounted, are made entirely separate from the shaft proper, and can be connected to it only when the two disks, N_5, N_6, are attracted by the electro-magnets, M_5, M_6, on these ends. When current is sent through each of these magnets, shaft *d* is locked to its two ends, *e*, *e*, and drives the carriage in a straight line, while if the current is sent through but one of the magnets, only one of the front wheels propels the vehicle, and, as the fore-carriage is mounted so it can turn, tends to steer it in one direction or the other, according to which wheel it is that is driving it.

All the control of the fore-carriage is therefore accomplished electrically through the wires that connect it with the carriage body. The two 60-ampere hour accumulators that furnish electricity for sparking the motor are also of abundant capacity to operate the clutches, as all the current necessary to operate the three clutches that are constantly in use is from 1.2 to 1.5 amperes at 4 volts. An extra pair of batteries is carried for use when the first set becomes exhausted and while it is being recharged.

In order that this arrangement, which we will call an "electric differential," shall operate properly and automatically, when the steering arm acts on the vertical steering column of the vehicle, it breaks the circuit of the electro-magnet, M_5, or M_6, which will be the inner one of the curve about to be described. To accomplish this, the steering arm, *E* (Fig. 2), is loose on the steering post and oscillates between the two branches of the differential arm, *A*, which is fastened to the post. A contact point, *B*, on the steering arm delivers current to the two spring-pressed contacts, *G*, and *D*, on the differential arm, which are connected to the two steering or differential clutches just mentioned.

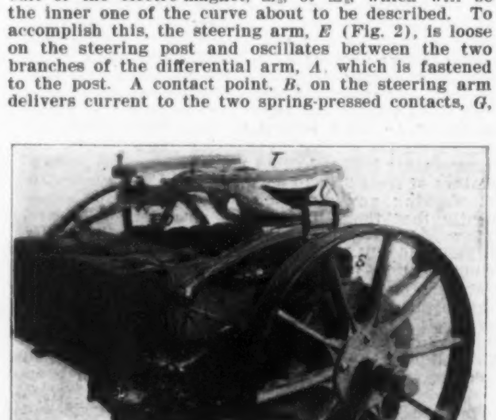


Fig. 5.—SIDE VIEW OF FORE-CARRIAGE.

When the operator wishes to turn to the right or left he moves the steering arm one way or the other, when one of the contact springs is compressed while the other ceases to press its contact button against that on the steering arm, and hence the circuit is broken to the corresponding magnet. As a result of this, but

one wheel drives the fore-carriage, and this tends to turn it.

Although the carriage has a tendency to turn in the direction desired (that is, although the "differential" is properly set), still it is necessary that the angle at which the driver wishes to turn be regulated mechanically. This is accomplished by the pinion, *P*, on the lower end of the steering post, which engages the teeth of an annular rack on the upper part of the fore-carriage. This mechanical steering arrangement constitutes likewise a safety steering device by which the vehicle can be guided, should any break occur in the wires or the current for any reason be suddenly cut off when the carriage is running full speed on a down grade.

The two illustrations of a Riegel fore-carriage complete were made from photographs of one of these machines after it had been tested by belting the two wheels (which, it will be noticed, are without tires) to a dynamo. The fore-carriages are all tested in this manner after they have been assembled and just as they are when attached to a vehicle. It will be seen from these two illustrations, and particularly from the side view, that the motor has attached to it all neces-

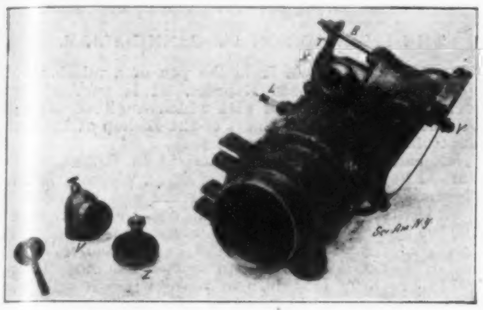


FIG. 6.—CYLINDER OF RIEGEL MOTOR.

sary accessories such as a carbureter, gasoline tank, *E*, water tank, *R*, radiator for cooling water, *S*, and gear cases, *B*, which inclose the large gear wheels and form at the same time a bearing for the ends of the driving shaft. It will be noticed, also, that the main elliptical springs, *A*, are reinforced by spiral springs. Should the weight of the carriage compress the latter springs too much, vertical cores passing through their centers would stop the top part of the fore-carriage from descending and damaging the radiating tubes or tanks.

The upper part of the fore-carriage is made of a very strong piece of steel and has mounted on it the fifth wheel plates, *T*, as well as the rack with which the pinion on the steering post meshes.

In the front view the copper case which conceals all the parts of the motor has been removed, so that these can be exposed to view.

The flywheel of the motor, which is placed at the front, is covered by a case which plays a very important role, for it allows of the complete accessibility of all the parts of the motor, such as the exhaust valve cams and levers, contact box of the igniters, and water pump with all its pipes, by simply removing the large copper case that covers all. On the top of the flywheel casing is an oil reservoir, *G*, which supplies a number of sight-feed oilers placed at the back, while the chain that operates the contact box, thus advancing or retarding the time of ignition, is plainly seen passing over the oiler and up through the hollow king-bolt of the fore-carriage.

The details of the flywheel cover are plainly to be seen in Fig. 7. The end of the motor shaft has a bearing, *B*, in the center of the cover, and this, with the

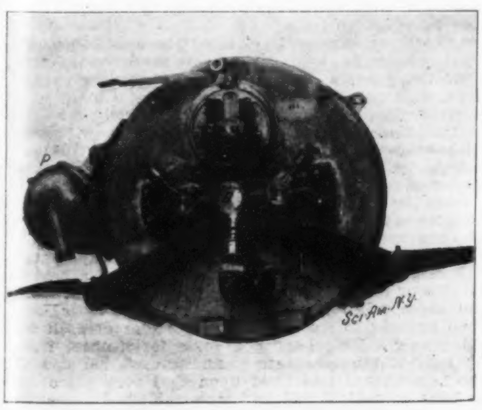


FIG. 7.—COVER OF MOTOR FLYWHEEL.

four lugs on its circumference, holds the cover in place. The motor shaft has a pinion on its end which meshes with three pinions inside the cover that have twice as many teeth as the driving pinion and that are keyed on their respective shafts, *A*, E_1, E_2. The last two of these shafts carry the exhaust cams, against which press the rollers of the exhaust levers, C_1, C_2. The projecting ends of these levers raise the exhaust valve stems at the proper times.

The shaft *A* carries the contact cam, which operates the make-and-break apparatus for producing a jump spark in the two cylinders. This apparatus can be plainly seen, since the cover is removed.

The pump is mounted on an arm, *H*, and is held in place against the flywheel by a stiff, flat spring. Its pulley is leather covered, which, together with the form of spring used for keeping it in contact with the flywheel, assures a sure drive and a perfect circulation of water.

The cylinders of the motor and their water jackets are each one an integral casting, so that there are absolutely no joints to leak.

The spark plug, *L*, is vertical when the motor is in position, and it is so located that it can easily be removed if necessary. The inlet and exhaust valves are easily accessible, and they can be removed on the road if need be without soiling one's clothes in the least. The axes of these two valves are in the same vertical line, *x*, *y*. The exhaust valve is the lower one and has its stem constantly pressed down by a flat spring. The inlet valve is in the top of the valve chamber, and is mounted on its seat, *Z*, on which it has first been ground, and which, as well as the valve, is entirely covered by the cap, *V*. This cap is held

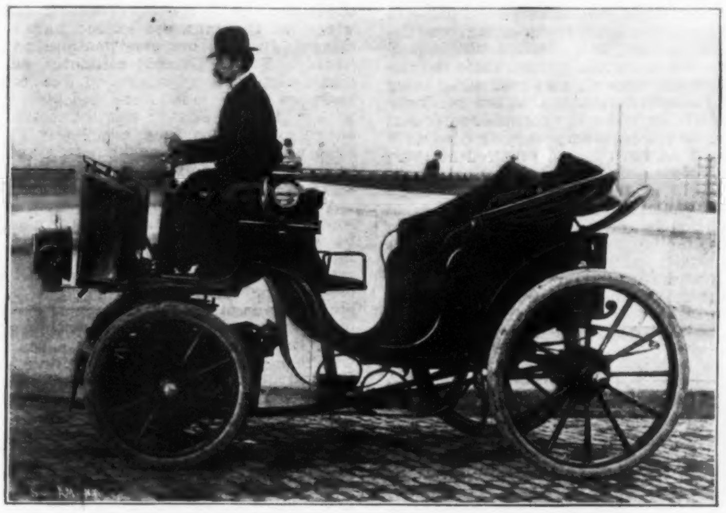


FIG. 8.—VICTORIA FITTED WITH FORE-CARRIAGE.

tightly in place by the arm, *T*, into the notched end of which fits the connecting rod, *B*.

In order to take out and grind the valves under the most unfavorable conditions (which is on the road, of course) it is only necessary to disconnect the inlet pipe and unscrew the nut of rod *B* in order to take off the cap and remove the inlet valve and its seat.

Through the large aperture thus opened, it is an easy matter to introduce a screw driver and grind the exhaust valve by turning it *in situ* on its seat. The seat is, moreover, depressed below the horizontal passage connecting the valve chamber with the bottom of the cylinder, so that it can be washed out, after grinding, and the emery used be carried off through the exhaust passage without getting into the cylinder.

The photograph of the steering column shows also the steel upper part of the fore-carriage, on which the controlling pillar is mounted. This steel frame is placed under the front part of the carriage body and has its ends fastened to the side bars of the latter. A square hole is cut in the floor for the pillar to pass through. *O* is the hollow king-bolt that connects the upper frame attached to the vehicle with the upper part of the fore-carriage proper.

FIG. 9.—TOURING CAR WITH FORE-CARRIAGE AND BEVEL GEAR DRIVE ON REAR AXLE.

After the front of the vehicle has thus been prepared, it is raised by a sort of sling made of rope, pulley and tackle, and hung from a hook in the ceiling. A man holds the fore-carriage by its springs, rolls it to its new position, and places blocks under the wheels and under the tanks at the back. All that is then necessary is to let the body of the vehicle down into place, drop the king-bolt into its hole, fastening it there with setscrews, and connect the wires to their proper clamps, and the tubular reaches to a universal ball joint under the fore-carriage.

We illustrate two carriages fitted with the regular Riegel fore-carriage. On the back of the dashboard is a box which contains two two-cell sets of 60 ampere-hour accumulators, one of which is held in reserve; a spark coil, and divers tools and accessories.

The electrical equipment is important, since the sparking of the motor and the changes of speed of the vehicle depend upon it entirely. Fully printed instructions are placed on the cover of the box on the dashboard, telling how to connect the wires, etc. The end of each wire is fitted with a suitable terminal that fits into a socket on the vehicle and is held firmly by a screw. In order to guard against the breaking of these wires by the constant vibration, which is apt to cause the well-known phenomenon of progressive granulation of the molecules of copper, each wire, although it has to carry only half an ampere, is made up of 110 very fine wires, which, with the insulating material, forms a wire ¼ inch in diameter.

The brakes employed are of two kinds: (1) Band brakes on the rear wheels, operated by a foot pedal; (2) the reverse gear can also be used because of the ease with which the magnetic clutches take hold.

Since with the use of the usual shifting gears used on gasoline automobiles the employment of the reverse as a brake is impossible when one is rapidly descending a grade, it is a great surprise to see the driver of a Riegel carriage, when going full speed down hill, by a slight movement of the controlling handle pass from full speed ahead to the reverse. The vehicle gradually loses speed, stops and begins to back. This result, which gives not the least shock or jar to the occupants of the carriage, is obtained because the reverse gear clutch does not attract sufficiently to lock suddenly, but takes hold gradually, allowing a relative slipping of the two faces while the momentum of the carriage is being checked.

The mounting of the accessory parts varies slightly on some vehicles such as landaus and delivery wagons. The steering column is inclined in some cases and supported in a bracket on the forward box. The carriages are all built after the designs of the carriage builders, and except that they have stronger wheels and axles, they cannot be told apart from ordinary vehicles.

The victoria shown in our illustration has boxes in front and in back for carrying packages or provisions, if one desires to take a day's outing in it.

In conclusion, we wish to say a few words about the

use of a single fore-carriage with several vehicles. Suppose we have, for example, a coupé and a victoria which are fitted with all the necessary parts (steering column, box, etc.), but which have but a single fore-carriage between them. Above each vehicle there must be a suitable hoisting tackle. After placing inclined blocks under the wheels, and another block under the back or heavy part of the transformer, the king-bolt is withdrawn and the front of the vehicle raised, the bundle of wires that attach it to the fore-carriage being first detached. All that is now necessary is to place the fore-carriage beneath the front of the other vehicle and attach it to the latter.

There is, therefore, a great advantage in possessing two elegant automobiles of an altogether different style, but drawn by the same motor.

For the delivery service of large stores the advantage is of a different nature. In such service, the fore-carriages become veritable horses, and instead of having one of them per vehicle two or three are made to act as motive power for a large group of wagons, the extra ones being, as it were, relay horses which, periodically, will replace the service horses while the latter are being inspected, cleaned, repaired, and having done to them all those little things that are generally done to automobiles only when the constant wear and tear of the parts, increasing every day, has led to a serious breakdown that can only be repaired at great expense.

All experienced automobilists know that it is not the cost of the fuel and oil that forms the chief item of expense, but particularly the cost of maintenance of taking apart, reassembling and of repairs. Who does not know the financial meaning of these simple words: "Have taken apart the whole vehicle; have found nothing; have put it together again." Several days pass so easily for two or three workmen at this exercise, the cost of which the manufacturer must not be asked to stand!

The economy in maintenance expenses is also evident, on the one hand in the diminution of serious interior breakages, and on the other in the short time needed, if one is hard pushed, to make a thorough inspection. In this respect the fore-carriages that we have just described present unquestionable advantages.

The entire absence of shock when the gears are changed, caused by the relative slipping of the magnetic disks, proves that, since the occupants of the vehicle do not feel any violent shocks, the gears, cranks, connecting rod, pistons—in a word, the delicate ensemble of the motor—does not feel any either. Its life must be lengthened, therefore, to a considerable extent.—For the above description and the illustrations we are indebted to La Locomotion.

NIPPUR'S GREAT LIBRARY.

SOME of the most important archæological material that ever came to America has just arrived at the University of Pennsylvania. A library of which every volume or tablet was written prior to Abraham's leaving Ur of the Chaldees was excavated in the recent campaign in Nippur. These treasures were brought to this country in twenty-two large cases, containing from six to eight boxes each. More than a year ago Prof. Hilprecht left Philadelphia for Constantinople, expecting to continue his work of organizing the new Semitic section of the Imperial Ottoman Museum, which occupies the third new building recently erected at the Sultan's order, and at the same time examine and study the immense results of the last expedition to Nippur, which had arrived at Constantinople. As Prof. Hilprecht was about to leave Constantinople the Sultan, who had theretofore on a number of occasions manifested his appreciation of the valuable services rendered by Prof. Hilprecht, presented to him, among other important antiquities, the larger part of the famous temple library which was excavated by the expedition of the University of Pennsylvania. Prof. Hilprecht in turn presented this magnificent collection of tablets to the institution which he represented.

A little over twenty-five years ago the intellectual world was startled by the announcement that Ashurbanapal's library had been discovered by the English explorers Layard and Smith, and that among the clay volumes there were accounts of the creation and deluge which much resembled the Biblical stories. It was then ascertained that these legends were copies of older tablets which belonged to Babylonian libraries in the southern part of the valley. For some time scholars have assumed that every important Babylonian city had its library, and that if they could be found most important data for the reconstruction of the early history of man would be forthcoming. Without detracting, therefore, from the importance of the discovery of this ancient Assyrian library at Nineveh, the announcement that the library of the Great Temple of Bêl, the most famous sanctuary of the early Babylonia, has been found surely must be regarded as of even greater importance. The scribes of Ashurbanapal made no copies of tablets from this library, for it had been thrown into ruin over sixteen hundred years prior to this time. The Elamite hordes under Kudur-Nankhundi, 2285 B. C., who destroyed nearly every city of Babylonia, threw into ruins at the same time the temple library at Nippur, in which condition it remained until excavated. This fact determines that every tablet found in its ruins belongs to the period prior to this invasion, or, in other words, was written before or about the time Abraham left Southern Babylonia for the Promised Land.

About twelve years ago, when Prof. Hilprecht first rode over the mounds at Nippur, he pointed out an extensive group of mounds south of the temple hill, which he regarded as the probable site of the temple library. About twenty-five hundred tablets were recovered from this mound in the first campaign. The mound was called Tablet Hill. Later excavations revealed many additional inscriptions, but on the recent campaign Prof. Hilprecht was able to establish definitely that his old theory was correct. In the brief space of about eight weeks a series of "book stacks," or rooms, were cleared by his field director, Dr. Haynes, and a rich harvest of nearly twenty thousand tablets was gathered.

In the uppermost stratum of this mound the excavators found coffins which had been buried in the early centuries of our Christian era. A great many antiquities were also gathered which belonged to the Jews who continued to live at Nippur after the return of Ezra and Nehemiah. Prominent among them were terra cotta bowls containing incantations and charms inscribed in Hebrew and Mandæan. Down the excavators went, through twenty-five feet of accumulations of débris, representing several millenniums of history, when they finally came on the library. Here they found a series of rooms, a number of which contained ledges or shelves built out from the wall, for the purpose of laying out the tablets in rows. The library seems to have been divided into two parts. There was a business section for keeping accounts, and the educational quarters, with a vast library of a literary character. Only the southeastern and northwestern wings of the immense edifice have thus far been cleared; in all about one-twentieth part of the entire library. Prof. Hilprecht estimates, on a basis of the discoveries already made, on the topographical appearance of the mound and the history of the temple with which the library was connected, that when the entire mound has been completely excavated it will have yielded at least one hundred and fifty thousand tablets, every one of which belongs to the third millennium before Christ.

The clearing of the library was continued a few weeks after Prof. Hilprecht's arrival at Nippur, when he withdrew the Arabic workmen from its ruins, owing to the shortness of the time at his disposal, and set them at work on the eastern fortifications of the city, at the same time having one of the architects make a ground plan of the rooms exposed. The complete excavation of this most important structure, with its precious literature of a long-forgotten past, will require several years of continuous labor. While the destruction of temples, palaces, libraries and works of art which the Elamites then accomplished must be regarded as gross vandalism, yet in this particular instance, so far as the people of this day are concerned, it was most fortunate, for doubtless the tablets, being mostly unbaked, would have been destroyed long ago and their contents entirely lost if the Elamites had not destroyed the library building. When the roof collapsed, the tablets, which had been laid in rows, classified doubtless according to their contents, fell from the shelves to the floor in heaps, in which condition they were found.

It was a glorious sight for the excavators. They had found inscriptions and other valuable antiquities in various parts of the mounds during the previous twelve years, but no discovery could be compared to this in extent and importance. One by one the tablets were carefully removed from their resting places by trained workmen. It was necessary to handle them tenderly, owing to the fact that they were moist from being buried for several millenniums in the earth. As they were taken from their resting places they were carried to the castle, which had been built by the excavators to house themselves and also the antiquities. After the tablets were thoroughly dried they were packed, ready to be shipped to Constantinople.

The contents of the library, so far as examined by Prof. Hilprecht while at Nippur and in the last year at Constantinople, proved to be most varied; in fact, practically every branch of literature known to the Babylonians is represented in the library. Among the inscriptions are hundreds of historical texts, dictionaries, or lists of Sumerian words with Semitic equivalents; lists of birds, animals, plants and stones; lists of words for chairs, stools and other articles of furniture; hymns, astronomical and mythological inscriptions, tablets which refer to the service and functionaries of the temple—how many garments the god Bêl wore, how many temples and shrines there were at Nippur besides those dedicated to Bêl, and what the revenues of the temples were; tablets containing grammatical sentences written by students, arithmetical calculations, etc. Naturally, in the brief time at his disposal up to the present, only the most cursory examination of the precious material could be made by Prof. Hilprecht; but, as he announced, "the methodical publication of the rich and varied contents of this unique literary library, the first of its kind so far excavated in Babylonia, and now constituting one of the most precious treasures of the University of Pennsylvania, will be taken in hand vigorously and constitute his chief task for the next twenty years."

When we reflect that until recent decades our knowledge of the period prior to Abraham was entirely dependent upon the first eleven chapters of Genesis, and that here is an entire library, which contains many thousand volumes written in that early age, we can at least realize that the future generations will have considerable knowledge of those early days, which until recently were regarded by many scholars as mythical, and yet no one can even conjecture what is contained in the larger part of the mound, which up to the present remains untouched.

Several versions of the creation and deluge stories older than those found in Ashurbanapal's library have been discovered at other places. One of these is dated about 2000 B. C. It would not be surprising to find that versions of the same accounts older than those already recovered would be found in the great Nippur library, besides other documents which would throw additional light on the early chapters of Genesis.

This is only one of the important discoveries of the recent campaign. Considerable attention was paid to the excavation of the great temple of Bêl, the foundation of which was laid between six thousand and seven thousand years before Christ. An ancient government palace of immense proportions, where the kings lived, belonging to the fifth millennium before Christ, and one of the ancient gates and walls of the city were uncovered. A government palace erected about 300 B. C. was completely and systematically excavated, besides numerous other buildings of less importance. Most valuable inscriptions in stone belonging to the earliest rulers of Babylonia, by the help of which the early history of mankind in the valley between the Tigris and Euphrates will be reconstructed, were discovered. Antiquities in coins, jewelry in gold, silver and bronze in great quantities; vases in enameled and plain pottery of all periods; seals and seal cylinders, such as the Babylonians used in connection with their business transactions; images of gods, playthings in terra cotta, bass-reliefs, weights, utensils in bronze, iron and silver, etc., were found. These are a few of the important things found, without mentioning the numerous facts ascertained and the many questions solved through the personal study of Prof. Hilprecht while in the trenches, which have important bearing upon the religious ideas and customs of the daily life of the Babylonians.

Only a small portion of the mounds at Nippur has thus far been completely excavated. Considerable work yet remains to be done on the temple. Only one side of the ancient government place has been cleared, and about one-twentieth part of the library. In view of the fact that the Sultan and his administrative body have manifested such a generous and friendly attitude toward the university, and especially toward her representative, who is the scientific director of the expedition, there is little doubt that this important work will be continued in the near future, especially as Prof. Hilprecht has already completed all arrangements toward this end.—New York Tribune.

THE PHENOMENON OF CANNIBALISM.

THE following article from the pen of a missionary appeared in the London Express. It is particularly timely owing to the doubt with which Anglican papers had received the recent report of the Bishop of British New Guinea on the same subject.

That cannibalism is still practised in British New Guinea after over thirteen years of sovereignty is no reflection on the Lieutenant Governor and his magistrates, says the Bishop of New Guinea. With an area of 90,000 square miles on the mainland and 300 islands in proximity, and a force of 150 Papuan police, it is wonderful that it is limited to so few districts. It is safe to prophesy that in five years' time it will be unknown within this portion of the empire.

It is just four years ago since I was first brought face to face with this gruesome practice. Scene, the northeast coast, 150 miles away from any government station—a district where we Church of England missionaries were the first to live among the natives.

In front of us a native grass hut with the skull and other bones of a victim of a cannibal feast hung up as spoils of war over the door, and the "consumer" justifying his action in the limited vocabulary that we possessed in common. He was a big-framed man, with nothing but a piece of cloth round his loins, a garment hammered out of the bark of the paper mulberry tree. He had a portentously big mouth, and he showed this to its full extent with a splendidly sound set of teeth and a tongue blood red from the juice of the betel nut.

He then stroked his gullet up and down with one hand, as with the other he pointed to the remains of his vanquished foe hanging over the door of his hut. "The government say it's wrong, and the missionaries say it's wrong; but it is very good!" This was his plea for cannibalism. He knows better now, does my village friend. Twice a Sunday for three years past he has attended divine service and learned that since the God man lived on earth a human life humanity is sacred and cannibalism is an outrage.

The year 1901 was marked by a heavy roll of victims to cannibalism. Whether the number exceeded those of previous years may be questioned. Each year, at any rate, we know better what is going on. Still, the fact that there were four white victims marked last year unenviably.

In February a party of diggers were making their way inland to the Yodda gold field, over some desperate country that experience alone can help one to realize, when they were cut off by a crowd of savages. Two were killed and eaten; another, a German, got away, but died a day or two afterward of exhaustion. The remains of the unfortunate men were found, and a party of their mates went out into the district and made horrible reprisals.

In April, on Easter Day, the "Queen of Seasons," James Chalmers, who for twenty-seven years had risked the dangers of missionary work among savage tribes, made his last attempt to win a wild district for civilization and the Prince of Peace, and the brave old Christian warrior met a similar fate with one white companion and twelve native helpers. The government had to treat the matter as they would the murder of peaceable settlers, and the expedition, being attacked by the cannibals, hammered them severely and burned their villages.

I need not describe the other instances of cannibalism that occurred last year, except to say that I have in my possession the lower jawbone of a boy of fourteen or fifteen, who was killed and eaten not more than three miles from the coast in September last. When brought to me it had still portions of flesh adhering to it. This happened some forty miles from our nearest mission station, and caused me special regret, because I had fixed upon that very place for our next extension, and had we established ourselves there a year ago that poor lad would be living now in peace and security. Objectors to missions please take notice.

But why do these cannibal feasts take place? Is it pure savagery, or is it a natural craving for animal food, which cannot be satisfied in any other way? I would offer an opinion on this subject with considerable diffidence. It is, in fact, not easy to get materials for a definite conclusion at all.

When natives are in the cannibalistic state we are not sufficiently in touch with them to know their language and discuss it thoroughly. By the time we are able to converse fluently with them they have abandoned the practice, and when this habit is once given up I know nothing that the Papuan is so soon ashamed of, and, being ashamed of, does not care to discuss.

Besides, he is not accustomed to think out the reasons for doing a thing, and probably never had a reasoned reason, or thought why he did it, till we asked him. All we can get out of the villager, in answer to the question why he eats man, are such

replies as: "It's flesh," "It's very good," or "It's our custom."

I think, myself, the consuming of the victim slain in the raid is the natural consequence of the raid. Tribes raid one another largely to take compensation for lives killed in a previous raid. "A life for a life" is New Guinean all over, and as the balance is never kept quite level there is always an account to be paid off. Apart from this obligation, I believe the New Guinea savage raids as a change from the monotony of agriculture. The people in that island are not nomadic tribes, but live a fairly settled life in villages, and grow all their own vegetable food.

The Papuan rebounds from severe agriculture and goes on a raid. Having raided and killed, he consumes, as a natural consequence, because the "flesh is very sweet." He eats it as he would eat pig.

It is smoked on the fire and dismembered just in the same way. Then it is wrapped round in green leaves and tied up with bine and carried home in little parcels on poles. The pole is balanced on the man's shoulder, and the little bundles decorate the pole on each side of the man's shoulder. The boys and girls eat it at once. Their parents put it before them, and they really do not inquire if it is pig or man. They eat it just the same. This, I suggest, is the true view of the horrid practice of cannibalism.

The idea that it is due to the natural craving for flesh meat is not borne out by my New Guinea experience, for the river district, where cannibalism is most prevalent in that land, is the area where native pig does most abound. The rivers have only to be somewhat flooded, and the pigs are driven onto the higher ground, where they are easily speared. I have heard of one part of the coast where only the arms and legs of human victims were eaten, but I have had no means of investigating this report.

As a Christian missionary I would draw what seems to me the obvious conclusion that Christian missions in such a land as British New Guinea are powerful aids to the cessation of bloodshed and cannibalism, and on humanitarian and imperial grounds, apart from any other, deserve far more general respect, not to add support, than they receive.

POULTRY AS A RESOURCE.

"One-half mile to America's greatest poultry farm." So reads the sign which confronts the traveler when he alights from the train at the little village of Dallas, in the mountainous anthracite region of Pennsylvania. As we climbed the steep hill in front of the station and traversed the winding road that leads to the country, my talkative guide told me all about the wonderful rise of the poultry industry. He said that the American hen, under the careful guidance of the poultry fancier, had developed possibilities as a wealth producer that were formerly not only unheard of, but unthought of. "Think of selling eggs at 25 cents each, which amounts to getting as much for one egg as two dozen ordinarily sell for," said the enthusiastic fellow, as we trudged along over the hills toward our destination.

In reply to my inquiry if he sold very many at the rate of three dollars a dozen, he said: "Yes, indeed, we sell hundreds of dozens at that price every season. We are sending out this week's orders to Panama, Australia, South Africa, Canada and to people in all parts of the Union. These foreign orders are for hatching purposes. We do not get so much for table eggs. We have a contract for furnishing eggs for the table of the Waldorf-Astoria Hotel in New York. They take about 600 dozen every week, and pay us eight cents per dozen above the market price. We have more orders for eggs than we have hens to lay them, so we send out buyers to gather them up from the farmers of the neighborhood. We have just taken on the biggest contract ever attempted in this country. We are going to furnish a New York company 3,000 dozen fresh eggs every week to be retailed in the grocery department of its big establishment. We will have to scour the surrounding country in order to meet all our contracts, but we will be able to do it."

By this time we had arrived at the farm. It consists of 82 acres. The building and yards of the immense plant cover over 35 acres, and the amount of floor space under roof amounts to a little more than 112,000 square feet. In addition to being the largest, the Meadow Brook farm is one of the best equipped plants ever built in this country or abroad. It is lighted by electricity, heated by steam, and watered by a system of pipes which are fed by an immense living well on the premises. Everything about the place is conducted on a wholesale basis. There is a root and vegetable storehouse where thousands of bushels of beets, carrots, turnips, cabbage, etc., are stored away every fall for winter use. This house is built below the level of the ground to protect its contents from frost.

The incubator building is the first place the visitor is shown. In this department there are 50 large Cyphers incubators, each holding 400 eggs. The total capacity of the incubators in use is 200,000 eggs. It takes 21 days for a chicken to hatch in these machines, and 28 days for a duckling to come through. If all the machines discharged their chicks and ducklings at the same time they could not be handled to advantage, so to overcome this difficulty some of the machines are loaded with eggs every day, while others of them discharge their young broods daily. By this system the age of the stock is graduated so that the number required for market matures daily, and is cooped and shipped without being kept on the premises an hour longer than is necessary. In order to bring this about, however, it can readily be seen that it is necessary for the proprietors to keep a great many birds "on the hoof," as the stockman would say. When the little chicks come from the incubators they are herded into pens. They advance through these pens from day to day until they are 90 days of age, when they are driven into the coops and sent to market. The squad that leaves the machines each day are supposed to keep company from the incubator to the frying-pan, barring those that are puny and have to be put back a few days, or those that are particularly hardy, and can stand to be moved up a pen or two, consequently, there must be thousands of birds on hand constantly to enable the proprietor to fill his daily orders. In one of the buildings there is an immense food cooker which will hold 1,000 gallons. It occupies two stories—being loaded from above and emptied from below. Several barrels of fresh meat and bone are dumped in here at once, the door is bolted down and a pressure of 70 pounds of steam is turned into it for 30 minutes, at the end of which time the entire substance, meat, bone and all, is reduced to soup. Mule meat is used almost exclusively in making this broth. The Meadow Brook farm is in the center of the anthracite coal district, so that aged and lame animals, or those killed by accident, are easily obtainable. The soup made from the flesh of the mules is used to mix with the food of the young fowls. Water is never mixed with their food from the time they leave the incubators until they are sent to market. They are given plenty to drink, but the soup from the meat of the mules is considered better for them in their food. Great quantities of bread are fed to the growing fowls. They consume from 600 to 1,000 loaves daily. Shell is purchased by the carload and ground by steam machinery on the premises. The food is carried about the place on the cars of a little tramway. When the track runs through the yards, as it must in some places, it is built on trestles so as not to injure or disturb the young fowls.

The killing house, where the poultry is dressed for the market, is deserving of especial mention. The floors of this house are inclined toward the rear wall, so that all water, blood, etc., may be drained off easily after a day's killing. In the height of the season the men go to work at 3 o'clock in the morning. There is a little tramway which traverses the entire plant and the live birds are brought to the killing house in cars. The arrangement of this house is as complete as it is possible to make it. It has long picking benches which extend the entire length of one side of the building. Each operator has a window to afford him plenty of light. There are scalding, vats, feather bins, cooling troughs, dripping racks, packing benches, feather presses, billing desks, ice breakers, platform and hanging scales, and numerous other little contrivances, so that thousands of birds can be turned out with a speed that seems incredible.

The manner in which the eggs are taken care of is a departure. The farmer's wife generally gathers them in her apron, puts them away in any sort of receptacle which happens to be empty and close at hand, and, after they have accumulated sufficiently to make it worth while, packs them in bran or sawdust, and takes them to the village store. A new and novel plan is in effect at Meadow Brook. There are 2,000 hens in the laying department. The daily product of this immense flock is from 1,000 to 1,200 eggs. At intervals throughout the day the eggs are collected, the date stamped upon them, then wrapped nicely in tissue paper, packed neatly in boxes holding a dozen each, and the chances are that if biddie cackles before noon, her egg will be broken that same evening by the cook as he prepares the 6 o'clock meal for the guests at the Waldorf-Astoria in New York.

Part of the business of the plant consists of supplying young ducks and chickens to summer hotels, clubs, high-class restaurants, steamship lines and market dealers, who cater to the best trade of the big cities. These broilers command a high price. A pair of ducks ten weeks old sell in the market for $1.80. An Irishman of the name of Pat McEvoy has the reputation of raising the finest ducks that go onto the Eastern market. Pat came over from the old country as a stowaway, got a job on a duck ranch, made a study of the life and habits of the fowls, and now he is a recognized authority in the science of producing fine specimens. He knows all sorts of tricks about the business. For instance, just before he sends his birds to market he puts something in their food that makes their skins as yellow as butter. These rich-looking fowls have come to be known as "McEvoy's Golden Broilers," and when they come onto the market with Pat's little tin trade-mark sticking in their bills, the dealers always pay in advance of the market for them. If Pat McEvoy ever makes up his mind to go back to Ireland he won't have to go as a stowaway.

There are many interesting facts in connection with the business. Ducks are much more difficult to raise than chickens, for the reason that they are the greatest cowards in the world. The difference between the two is noticeable from the start. When a number of chicks are liberated from the incubators they walk boldly out into the light, and begin a critical survey of their surroundings. They are intrepid from the start. It is not that way with a duckling. It will peep out of the incubator, become alarmed at the strange sights its young eyes behold for the first time, and make a dash for a dark corner of the incubator. It takes considerable coaxing to get them to venture out and make a start for themselves. They do not outgrow their fear. When a stranger enters their pen they rush pell-mell to the opposite side and pile upon each other several feet deep. As a result of such a scare there will always be several dead ducks and a number of crippled ones. It is estimated that a duck loses in weight every time it is frightened, so it is a matter of good business to keep strangers away from the duck pens. Few visitors are allowed to go there. One of the best ways to get a flock of young ducks to venture and forage for themselves is to put a young chicken among them. They are quick to follow a leader, and when young Mr. Chicken, who is not afraid, leads off, the ducks are right after him. They also improve their habits and get better manners from associating with the chickens. But they are a timid folk. A light has to be kept burning in their pen all night. If they are left alone in the dark it is not long until the vivid imagination of one of them conjures up something at which to get scared. He will sound the alarm and the panic that follows is something terrible. The keepers go through at regular intervals during the night. The ducks become very fond of the men who feed them and care for them, but any other breathing thing causes them to go to pieces.

These machine-made fowls lack a great many characteristics of ordinary poultry, and have some ways not common to them. A person has a tendency to pity the shrinking little orphans when they stagger out of the incubators, possessed of barely enough strength to toddle along. They are a motherless lot of little waifs who have to face life without the protection and sympathy of parental care. But they seem to get along first rate, and probably do not miss old biddy's attentions on account of never having known them. When feeding time comes the keepers have a peculiar call which never fails to bring the tiny feathered beauties in swarms from every direction. The attendants also have another sound which is intended to imitate the whirring noise of a hawk's wings. In event of a storm coming up suddenly they can clear the yards quicker than it takes to tell it by sounding this alarm, which the little birds soon learn to be on the lookout for. The natural enemy of the young chicks and ducklings is the rat, but several ferrets are kept on the place constantly and the loss from the depredations of the rodents is small.

The development of the poultry industry, especially in the United States and England, is one of the marvels of the time. In addition to the fanciers who devote their attention to the production of ordinary fowls, we have pigeon ranches and ostrich farms, and they are nearly all prospering. It takes capital, perseverance and a knowledge of the business to succeed, but there is a constant market at prices which are very remunerative. The proprietors of Meadow Brook have $60,000 invested in their plant.—American Land and Title Register.

NEW FOOD PLANTS IN YUCATAN.

The gardens and fields of Yucatan are filled with succulent vegetables and odorous herbs unknown to the outer world. In the cultivated fields, at the proper seasons, are grown classes of Indian corn, beans, squashes and tubers for which we have no name, for the reason that we have never seen or heard of them.

The forests and jungles contain fruits that, excellent even in their wild state, could be made delicious by scientific care and cultivation. There are half a score of wild fruits that offer more promising results than did the bitter wild almond, the progenitor of the peach.

It is my purpose to bring to notice these promising subjects for cultivation in a series of reports made with the object of attracting the attention of those interested in this line of research and practical work.

The writer holds himself in readiness to supply any person who, or society which, desires the seeds or roots mentioned in these reports for the purpose of study, making only such charges as will cover the actual expense incurred.

The most important of the large cereals is the maize of the Mexicans—the Indian corn of the Americans and the ixim of the Mayas of Yucatan. Like several other vegetable products, its origin as a cultivated plant is enveloped in obscurity, the wild plant from which it was evolved not yet having been identified. Many believe that the cultivated plant was born somewhere between Yucatan and the tableland of Mexico. The mother plant was probably a grass, and the new grain spread to all sections, each one giving it certain characteristics until the varieties grown in the North hardly seem related to those of the southern lands.

Yucatan has six varieties of this grain, and the Maya Indian reverently speaks of it as the "grace of God."

The large-stalked, large-grained class known to the natives as xnuc nal (pronounced shnook nál) is the most prominent and has by far the greater acreage devoted to its cultivation on the peninsula (Yucatan). It is planted in May, is fully matured in January, and then is left to harden and season until gathered as needed. This class most nearly resembles our Indian corn. It has both the white and yellow grains. Under the haphazard methods of the native Indians, the corn produces in the limestone soil of Yucatan from 20 to 30 bushels to the acre. Under favorable conditions, this yield is often doubled.

The "xmehenal" (shmehenál) is a small, quick-growing variety, about the size of our pop corn. The plants are rarely 4 feet high, and the natives have a saying that the cock can pick the flowers of the true xmehenal without stepping off the ground. One variety matures within sixty days of its planting, and the second needs but fifteen days more.

The xmehenal xtup (shtoop), planted in May, can be gathered in July, and, while the production per acre does not quite reach the figures of the xnuc nal, it has a greater capacity of resisting the extremes of heat and dryness.

The natives of Yucatan prefer the native corn to that imported from the United States, and will cheerfully pay the higher price demanded in times of scarcity. They state that our method of kiln drying injures the grain. They allow the grain to harden and dry slowly in the ear upon the stalk.

The plant, or rather the running vine, known as the macal box (makal bosh), produces a tuberous root of great nutritive value. Entire families have lived upon this root for weeks at a time and were healthy and well nourished. This plant is very productive. About the middle of May the green shoots first appear above the earth. They grow rapidly and in November are ready to be dug. The tuber is about the size of a large Irish potato and is of a purplish color, like a certain class of sweet potato. It can be cooked in the same way as the sweet potato. The plant is hardy. A long drought may cause the vine to wither, but with the lightest rain it springs up anew. The roots left in the ground as too small for food propagate the plant, and each year the yield increases. It seems to be a kind of native yam; it grows in almost any kind of moderately rich soil, and when cultivated intelligently should be of certain value as a food plant. The xmakin macal (shmakeén makál), like the macal box, appears in May and is gathered in November, but it yields only one or two tubers to the plant. These, however, are of large size, resembling enormous Irish potatoes. I have seen four of these great roots fill a bushel basket. The interior is white and seems to be nearly pure starch. It is planted as we set out pota-

toes. The plants grow close together, and, while I have no exact figures, the yield per acre should be phenomenal, so far as weight of product is concerned.

Xmehen chi-can (shmehen chi kan) seems to be a kind of artichoke, weighing when mature about a pound. The plants are running vines, rarely more than a yard long. An acre will yield an immense crop under favorable conditions. The plant, sown in August, can be gathered in November.

Xnuc chi-can is a larger root, weighing when mature about 3 pounds. It is a hardy plant and produces well. Both of these roots are eaten roasted or boiled, and many like them raw. Some of the roots sent with this report as specimens are not of the sizes given, as they have been by force of circumstances taken out of season.

[Continued from SUPPLEMENT No. 1396, page 22369.]

A REVIEW OF THE EXISTING METHODS OF CULTIVATING ANAEROBIC BACTERIA.*

By OTTO F. HUNZIKER.

EXCLUSION OF ATMOSPHERIC OXYGEN BY MEANS OF VARIOUS PHYSICAL PRINCIPLES AND MECHANICAL DEVICES.

THIS category embraces all those methods and appliances that do not belong to any of the preceding principles. They are arranged as follows:

The atmospheric oxygen is excluded:

A. By deep layers of solid medium.
B. By layer of oil.
C. By layer of paraffin.
D. By mica or glass plates.
E. By boiling the medium to expel the air and sealing the apparatus.
F. By the use of the fermentation tube and its modifications.
G. By inoculating into a hen's egg.

A. DEEP LAYERS OF SOLID MEDIUM.

Hesse (1885) and Liborius (1886) recommended the following method: Pour into a test tube, Erlenmeyer

FIG. 37.

flask, or deep Petri dish, a sufficient quantity of nutrient gelatin, nutrient agar, or blood serum, to form a layer of from 5 to 20 centimeters deep. Boil the medium for at least five minutes to expel the air, cool down to a temperature of about 40 deg. C., inoculate the medium, distributing the inoculating material well through it. Care must be taken not to shake the tube or flask; after inoculation cool rapidly by standing the apparatus in cold water until the medium is set. In this way a large number of isolated colonies usually develop, which are either distributed all through the medium, or appear only in the higher zone, or inhabit exclusively the lower layers. The sharply marked distribution of the colonies over the different zones, their size and other characteristics permit a fairly accurate estimate of their relative want of oxygen. The inoculation is made with a long, firm platinum wire, which has previously been brought into contact with the culture material, or a long capil-

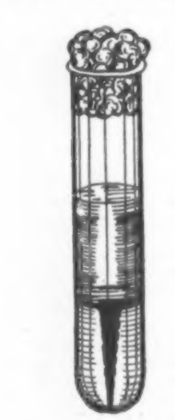


FIG. 38.

lary pipette may be used, into which the culture has been introduced by suction. This simple method, which is very effective even in the case of the strictest anaërobes, is being used successfully in many laboratories.

Often a layer of sterile medium is poured on top of the inoculated layer after the latter has solidified. In order to gain access to the colonies the tube is broken. Sanfelice, 1893, warms the bottom of the tube and shakes the column of agar out into a sterile glass plate, where it can be cut into slices, the colonies can be examined and subplanted.

Esmarch recommends the following procedure: Make Esmarch roll cultures in the ordinary way. Stand the tubes containing the roll cultures in ice-cold water and pour liquefied gelatin into the cavity of the tube. Upon cooling the gelatin, the inoculated medium is almost entirely protected from the access of the atmosphere.

Schill's modification of the above method.—Pour from 10 to 15 cubic centimeters of liquefied gelatin or agar into a large test tube, inoculate it with the anaërobic organism, insert a narrow sterile test tube into the inoculated medium in the large tube and roll the whole apparatus in ice water or on a cake of ice. When the operation is completed the thin layer of solidified medium in the outer tube is protected from the air by the inner, smaller test tube. Both methods have the advantage over the ordinary Esmarch roll culture that they furnish a support for the thin layer of culture medium, and prevent it from sliding down to the bottom of the tube.

B. LAYER OF OIL.

This method, illustrated in Fig. 37, and used by Pasteur and Hesse, appears to be of little if any advantage over those described under *A*.

Method.—Pour about 7 cubic centimeters (in case of small tube) and 15 cubic centimeters (in case of large tube) of liquefied gelatin or agar into a sterile test tube, boil to expel the air, cool to 40 deg. C., inoculate without shaking the tube, cool rapidly in ice water until the medium is set and pour a layer of sterile oil on the surface of the inoculated medium.

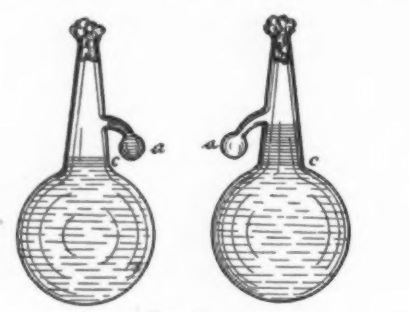


FIG. 39.

This method may also be used for stab cultures (see Fig. 38). Cultures prepared in this way have the disadvantage that the oil which adheres everywhere renders them somewhat objectionable.

C. LAYER OF PARAFFIN.

Kitasato was the first to use paraffin as a cover over the inoculated medium. He poured liquefied paraffin on the inoculated medium. This method has several disadvantages; with the paraffin foreign germs may be introduced into the medium, the neck of the culture apparatus is smeared with the paraffin, and the heat of the liquefied paraffin may be injurious or even detrimental to the development of the inoculated organisms.

Kasparec (1896) introduced the following method: Use a flask with a long tapering neck as illustrated in Fig. 39. Blow a small lateral tube, terminating in a bulb, into the neck of the flask, about 1 centimeter above *c*. Fill the sterile flask with bouillon almost to the neck, then add about 3 cubic centimeters of liquid paraffin and sterilize the whole in the steam sterilizer. The heat expands the bouillon and causes the paraffin to rise in the neck of the flask and to overflow into the lateral tube, filling the bulb, *a*, so that after sterilization there remains only a very thin layer of paraffin on the surface of the bouillon at *c*. During the heating a large portion of the air absorbed by the medium is driven out, and its re-absorption, while the flask is cooling, is prevented by the paraffin. When cool inoculate the bouillon by piercing the solid film of paraffin with a platinum needle, loop or capillary glass tube charged with inoculating material. Now liquefy the paraffin in the lateral bulb by carefully heating it over the flame and pour the liquefied paraffin on the thin film of solid paraffin on the sur-

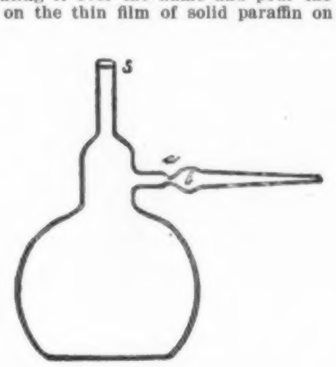


FIG. 40.

face of the medium by inclining the flask slightly. Upon hardening this additional layer of paraffin constitutes an almost perfectly air-tight cover which becomes even more effective by being pressed into the tapering neck when the culture medium is warmed in the incubator. This seal is made tighter yet by the pressure of the gases generated in the culture. When the flask is to be emptied, warm the vessel and incline the flask so that the liquefied paraffin will flow over into the lateral bulb.

This method is likewise advantageous in the preparation of toxins, as the culture can be easily transferred in a very pure condition to the filter after the warmed portion of the neck of the flask has cooled and the paraffin in the lateral bulb has hardened.

Park (1901) modified the above method as follows: Use tubes or flasks containing sterile nutrient glucose bouillon. If non-spore-bearing anaërobes are to be cultivated, cool the medium quickly, inoculate and cover the bouillon with a layer of very hot, sterile paraffin. Where absolute exclusion of oxygen is desired sterilize the tubes containing the medium and the layer of paraffin in an autoclav; this renders the bouillon free from oxygen. Spore-bearing bacteria are inoculated through the liquid paraffin before the bouillon is cooled down. In case of bacteria without spores the medium is first cooled down and the inoculation is made by breaking through the solidified film or by heating and melting the paraffin in the gas flame. A pipette charged with the culture can then be carried through the hot paraffin into the cool liquid medium.

D. MICA OR GLASS PLATE.

Koch's method.—Prepare a gelatin plate in the usual way. Before the inoculated gelatin is completely congealed cover it with a thin, sterile blade of mica. The mica blade has the thickness of a thin sheet of writing paper. It must be well flamed, and after cooling so placed upon the semi-liquid gelatin that no air bubbles form beneath it. It must cover the gelatin completely and perfectly.

Sanfelice modified Koch's method by using a glass plate instead of a mica plate as a cover. Pour the

FIG. 41.

inoculated gelatin or agar into the sterile cover of a Petri dish and when the medium is nearly congealed press the other half of the Petri dish, bottom downward, gently into the medium.

E. EXCLUSION OF AIR BY BOILING THE MEDIUM AND SEALING THE APPARATUS IN THE FLAME.

Hufner and Rosenbach use a heavy 250 cubic centimeter flask with flat bottom and tapering neck as shown in Fig. 40. Immediately below the tapering neck a lateral tube projects horizontally. At its union with the neck it measures 3 millimeters in diameter. At *a* the lateral tube is constricted, then blown out into a small bulb which terminates in a capillary tube 8 centimeters in length. The bulb, *b*, constitutes the reservoir for the inoculating material.

Method.—Pour about 20 cubic centimeters of medium into the flask by means of a drawnout pipette. Then taper the neck still more so that it can be sealed easily and quickly. After cooling dip the lateral tube into the inoculating material and by means of suction at *S* draw the latter up until it reaches *a*. Seal the outer end of the lateral tube in the flame until a powerful stream of vapor evolves from the narrow opening of the neck. After the steam has escaped for about four minutes seal the tapering neck in the flame. When the medium is cooled down to 40 deg. C., slightly warm the inoculating material in the reservoir of the lateral tube. By this means it is forced into the flask, where it should be well distributed all through the medium by slightly shaking the flask. Now melt off the lateral tube at *a* and place the flask in the incubator.

Vignal's Method.—Taper an open glass tube (Fig. 41) at one end and plug it with absorbent cotton at

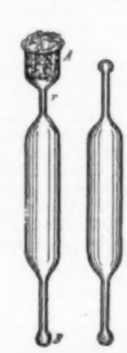


FIG. 42.

the other. When sterilized dip the tapered end of the sterile tube into the inoculated medium (liquefied agar or gelatin) and fill the tube by suction at *a*; when filled seal both ends in the flame. In order to make subcultures from the isolated colonies developed in this tube, cut the tube in two.

Roux's pipette cultures: (Fig. 42). The pipette consists of a glass tube drawn into a capillary tube at its lower end and constricted at *r*.

Method.—Seal the capillary end, *B*, in the flame, insert a loose cotton plug at end, *A*, and sterilize the apparatus at 150 deg. C. Break off the seal at *B* and dip the capillary tube into sterile, liquefied nutrient agar or gelatin which has been boiled immediately before. When the tube is filled up to constriction, *r*, press the finger tightly over the upper opening, *A*, and quickly raise the tube into an oblique position. This will prevent the medium from running out. Now seal at *B* and then at *r* in the flame. For inoculation

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open one end, make a thrust with a fine, infected glass needle, and seal again.

Nikiforoff (1890) constructed the capillary tube shown in Fig. 43. The apparatus consists of a reservoir, *a*, which is constricted and sealed at one end, *b*, and drawn out into a capillary tube about 25 centimeters long at the other end, *c*. The capillary tube is U-shape. Heat the reservoir, *a*, of the sterile capillary tube, then dip its open end, *c*, into a test tube containing sterile water. By letting the reservoir cool, a little of the sterile water is sucked up into it. Now draw the capillary tube several times through the flame and invert it in a test tube containing the inoculated medium. The end of the capillary tube should be near but should not touch the surface of the medium. Heat the capillary tube and its reservoir, causing the inclosed water to boil, and when most of the water has escaped from it in form of vapor, immerse the open end of the capillary tube in the medium in the test tube. Upon cooling a vacuum is formed in the capillary tube and the inoculated medium is drawn up and fills the entire capillary tube and the reservoir. Now remove the test tube and seal the capillary tube at its curve in the flame. For inoculation break the seal, introduce a fine capillary tube charged with inoculating material, and then seal the tube in the flame.

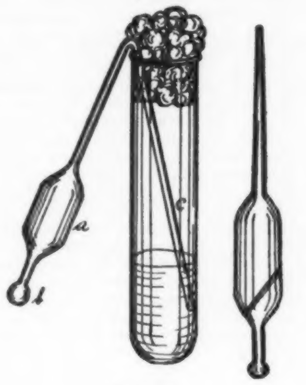


FIG. 43.

Van Senus (1890) uses a glass tube about 1 meter in length and 6 millimeters in diameter (Fig. 44). End *a* is drawn out into a narrow opening and wrapped up in cotton; end *b* is plugged with cotton.

Method.—Pour into a sterile test tube about 20 cubic centimeters of liquefied, sterile agar or gelatin and inoculate it. Remove the cotton from end *a* of the glass tube and immerse end *a* in the inoculated medium by pushing it through the cotton plug into the test tube. While the U-shape is being turned upward apply suction at end *b* till the medium reaches the curved part. Then turn the latter down, the liquid will now fill the rest of the tube by itself. Seal end *a* in the flame; the cotton plug at *b* prevents contamination.

For reaching the isolated colonies proceed as follows: Mark the place, where a well isolated colony is located, with concentrated H_2SO_4 by means of a glass rod. Wash off with sterile water, scratch with file, and break the glass tube. The colony is now ready for examination and sub-plantation.

Schmidt (1895) uses a test tube into which a monoperforated rubber stopper is well fitted; the perforation carries a glass tube reaching to the lower surface of the rubber stopper. The glass tube extends upward about 16 centimeters and is then bent into a U-shape as shown in Fig. 45.

Method.—Fill the sterile test tube with bouillon up to 5 millimeters below the upper edge of the tube, carefully insert the rubber stopper carrying the glass tube so that the air escapes through the latter. The stopper is pushed down until the medium reaches the upper end of the glass tube. If possible prevent the flowing over into the turned-down part of the glass tube. If gas bubbles have remained in the test tube force them out by lightly striking at the sides of the tube. If during the subsequent sterilization so much of the liquid evaporates that the glass tube has become empty, replace the evaporated medium by fresh, sterile medium. The tubes prepared in this way can be stored away indefinitely without becoming contaminated. In order to inoculate remove the stopper, inoculate the medium in the tube, and replace the stopper carefully so that the bouillon rises into the glass tube.

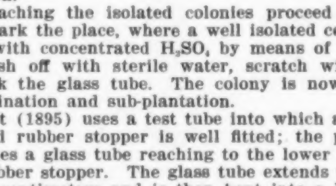


FIG. 44.

An ingenious and simple device has been invented by Wright (1901), (Figs. 46 and 47). The apparatus consists of a system of glass and rubber tubes standing in an ordinary test tube. *A* (Fig. 46) is a glass tube somewhat constricted at each end; *B*, *C*, and *E*, are short pieces of rubber tubing; glass tube *D* carries in its upper extremity a small cotton plug. The test tube contains some culture fluid as indicated in Fig. 46.

Method.—Arrange the apparatus exactly as shown in Fig. 46. To expel the air from the fluid, boil the culture medium immediately before inoculation over the flame without removing the inner system of tubes. Then cool the apparatus by placing it in cold water and inoculate the liquid medium in the test tube in the usual way. Draw the fluid up into the system of glass and rubber tubes to a level above the rubber tube *C* by suction. Compress rubber tube *E* between the fingers to prevent the down-flow of the fluid. Now push downward the system of tubes in such a way as to bend rubber tubes *B* and *C* in the manner shown in Fig. 47. If the test tube and the inner tube system are of suitable size the rubber tubes mentioned will remain in this bent position. The fluid in tube *A* is thus contained in a water-tight space sealed by the acute angle of the rubber tubes. When it is desirable to transplant some of the culture the tube system is straightened out; this will allow the fluid in them to flow out into the test tube, where it is accessible to the platinum loop in the usual way.

F. THE FERMENTATION TUBE AND ITS MODIFICATIONS.

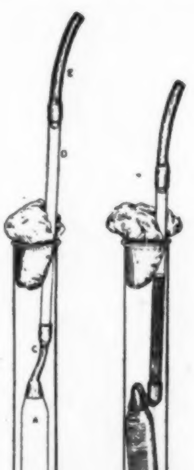
The methods and apparatus belonging to this type deserve special mention owing to their great simplicity and efficiency.

Previous to the invention of the fermentation tube Pasteur devised an apparatus (Fig. 48) which operates on a similar principle. It consists of a flask, *a*, which contains the liquid nutrient medium. Tube *b* is conducted into a porcelain dish containing the same medium as the flask, tube *c* serves for the purpose of introducing the medium and the culture. It carries a glass turn cock, *e*, above which it is extended into a short rubber stoppered bulb, *f*, which forms the reservoir of the inoculating material.

FIG. 45.

Method.—Boil the medium in flask *a* and in porcelain dish *d* for one-half hour simultaneously to drive the atmospheric oxygen from the medium. The evolving vapor forces the medium out of the flask, but the liquid thus freed from air returns back into the flask. The process repeats itself several times during the boiling. When boiled for the required length of time cool apparatus and medium. While cooling cover the medium in the porcelain dish with a layer of sterile oil to prevent a subsequent absorption of oxygen from the air. Fill *f* with the culture material and seal with the rubber stopper. When apparatus and medium are cool introduce a part of the culture material from reservoir *f* into the medium by quickly opening and closing turn cock *e*. The latter must fit perfectly. Now submerge the outer end of tube *b* in sterile mercury for the purpose of collecting the gases formed by the bacterial activity, and place the apparatus in the incubator. For a control test the author uses a flask as shown in Fig. 49. It is twice as large as that shown in Fig. 48, and filled only one-half with medium so that the culture is freely exposed to atmospheric oxygen.

Smith found the fermentation tube to be an apparatus of considerable antiquity and of unknown origin.



FIGS. 46 AND 47.

He says: "In Detmer's pflanzenphysiologischem Practicum I find it figured as Kühnesches Gährungsgefäss, More recently it has been adapted by Einhorn for the quantitative determination of sugar in urine and by Doremus for that of urea in the same fluid." Smith, in 1889, first conceived the value and made practical application of this tube with reference to anaërobioses and gas-formation among bacteria. The illustration (Fig. 50) represents a model fermentation tube. With regard to its construction Smith says: "In the construction of this simple bit of apparatus several points must be borne in mind. The bulb should be large enough to receive all the fluid contained in the closed branch. Moistening the plug imperils the purity of the culture. If the bulb is sufficiently large this difficulty will not arise. The connecting tube should not be too small, for then the filling and emptying of the closed branch becomes very tedious. Nor should it be too large, otherwise the anaërobic properties of the fluid in the closed branch may be less effective. Lastly, the angle formed by the two branches of the tube must not be too acute, otherwise the tube must be tilted so much during the transference of the fluid from the tube to the closed branch that there is danger of its moistening the plug or even running out of the bulb."

Method.—Heat the fermentation tube containing peptonized, sterile glucose bouillon in the steam sterilizer, cool, and inoculate it with the culture in question. In case of a pure anaërobic culture the growth will take place in the closed bulb and the line of demarkation between the turbid, teeming liquid of the closed branch and that of the bulb and connecting tube is sharply drawn.

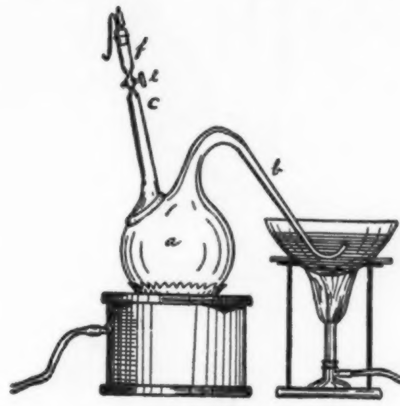


FIG. 48.

In 1899 Smith recommended a slight modification of the above method, using the same fermentation tube.

Method.—Kill a guinea-pig, rabbit, pigeon or other small animal with chloroform; tear pieces of the internal organs, more particularly of the spleen, liver and kidneys, as large as peas or beans from the organs with sterile forceps and quickly introduce them into the fermentation tubes, containing ordinary sterile, peptonized bouillon. The tissue should be eventually forced into the closed branch of the tube with a sterile platinum wire. A series of tubes are prepared at one time and placed in the incubator for several days to reveal any contaminating bacteria from the air or from the introduced tissue. Tubes provided in this way with bits of sterile tissues furnish most favorable conditions for the cultivation of anaërobes. They may be kept indefinitely, and when partly dried out they may be refilled with sterile water. Anaërobes will still multiply freely in them though they have not been reboiled. In fact, boiling would cloud the bouillon by coagulating the albumin from the introduced material. It is frequently very desirable to have on hand fluid cultures of anaërobic species for the study of morphological and physiological characters, a fact which makes this method especially valuable.

Smith constructed two more apparatus for liquid culture media belonging to the same fermentation tube principle. Being of large capacity they are especially adapted for the cultivation, on a large scale, of the tetanus bacillus for the production of a tetanus toxin.

In apparatus illustrated in Fig. 51 there are two bulbs, *A* and *B*, of nearly equal capacity, connected with a heavy rubber tube, *C*, which carries a clamp, *D*, to regulate the communication between them. This apparatus is best manipulated in a tin rack, *F*. The bouillon occupies the whole of *A* and all below the dotted line in *B*. It is inoculated by transferring the culture material with a platinum loop or pipette through the cotton plugged opening, *E*. The growth travels down into bulb *A* within 24 hours.

FIG. 49.

Fig. 52 represents an apparatus consisting of a stout liter flask, *A*, into which is fitted a rubber stopper, *c*, carrying a 100 cubic centimeter pipette, *b*, with the lower portion bent as shown in Fig. 52, and the upper shortened and provided with a cotton plug. The bouillon fills the flask completely and extends down the narrow tube to the dotted line in the bulb. The inoculation takes place through the opening, *d*, the growth proceeds unaided along the narrow tube and reaches the flask in from 24 to 36 hours.

The second form (Fig. 52) cannot be autoclaved when filled, as some of the fluid will be thrown out.

To obviate this the flask is only partly filled and the extra bouillon required is autoclaved with it in an ordinary flask. There is no difficulty if the Arnold sterilizer is used.

Hill (1899) constructed the fermentation tube shown in Fig. 53. It differs from that of Smith in that the open bulb has twice the capacity of the closed branch. This does away with the danger of wetting the plug, when the gas pressure in the closed branch forces the liquid into the open bulb. The closed branch is sealed by means of a conical ground glass stopper, S. The stopper is made thimble-shape to avoid the danger of cracking under high temperatures, which might affect a solid stopper. This arrangement enables the experimenter to examine the liquid in the closed branch without disturbing the liquid culture. In addition to these advantages it permits a more ready and thorough cleaning, and simplifies the process of filling.

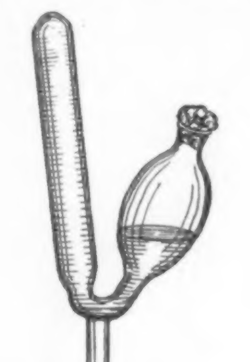


Fig. 50.

6. THE HEN'S EGG AS A CULTURE MEDIUM FOR ANAEROBIC BACTERIA.

Hueppe (1891) recommends the following procedure: Use freshly laid eggs. Clean the shell from all foreign matter; sterilize it by washing it in a solution of sublimate; rinse in sterile water and dry the shell with sterile cotton. With a flamed instrument make a small opening at the point of the egg. Through this opening inoculate by means of a platinum loop, platinum needle or capillary tube. Then cover the opening with a piece of thin, sterilized paper and seal hermetically by covering the paper with a film of collodion.

Pearmain's and Moor's Method.—Wash the newly laid egg in a soda solution; lay it in a 1-2,000 solution of bichloride of mercury for a short time; then rinse the egg thoroughly in water that has been well boiled, finally rinse it in strong alcohol and ether immediately before inoculation. For inoculation pierce the shell with a strong sterile needle and introduce the inoculating material by means of a glass capillary tube, from which it is blown with great care, close the hole with sterile cotton wool.

Macé (1901) recommends shaking of the fresh egg so that the yolk mixes well with the white. Instead of just washing the egg with sublimate for a short time Macé lets it soak in the sublimate solution for 24 hours.

COMBINED APPLICATION OF TWO OR MORE OF THE ABOVE PRINCIPLES.

Little need be said with reference to the apparatus that belong to this category. It is obvious that the large number of methods introduced permits a great variety of combinations that may be successfully used in cultivating anaërobic bacteria. Thus for instance, where it is desired to cultivate bacteria in hydrogen atmosphere, instead of forcing the air out by the current of hydrogen, the apparatus may first be partly or wholly evacuated by means of a vacuum pump, then it is connected with the Kipp generator. The exhaustion and filling may be repeated alternately several times. This combination has been used and recommended by Pasteur, Novy and other experimenters.

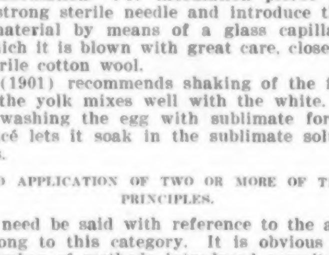


Fig. 51.

Where large apparatus are used, as those of Novy (Fig. 24), Zubinsky (Fig. 16), Gabinsky (Fig. 23), etc., a vessel containing a concentrated solution of alkaline pyrogallol may be placed in the apparatus immediately before it is sealed, for the purpose of absorbing any traces of oxygen that may still remain in the apparatus after the current of hydrogen has been passed through. This combination is especially desirable, where it is not convenient to use a continuous current of hydrogen, in which case the apparatus is sealed when filled with the gas. Traces of oxygen that may enter the apparatus as the result of a diffusion of the gases through imperfect seals will then be made harmless by the absorbing power of the pyrogallol.

Again, reducing agents may be added to the medium in addition to the use of any one of the other principles. The relative efficiency of the various reducing agents in use has been treated in chapter iv. and need not be discussed here.

Deep layers of medium are also often used in combination with any one of the other principles.

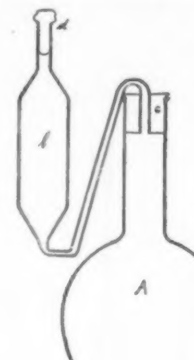


Fig. 52.

In addition to these optional combinations Nenki (1880) invented the apparatus shown in Fig. 54.

Method.—Fill the tube up to a with inoculated medium and close it with a perforated rubber stopper. Through one perforation push a glass rod, b, terminating in a glass stopper of ground glass. This stopper must fit well into the constriction at c so that the contents of the bulb, T, are completely separated from the liquid medium above. In the second perforation insert a glass tube, d, and connect the outer end with an evacuator. During evacuation the bulb is placed in a water bath at 37 deg. C., and the glass rod, b, is pulled up so that the stopper is located about at a. As soon as the air is driven out, a fact which is indicated by the jerky cooking—and striking of the fluid against side of the apparatus—the glass rod is pushed down by a careful turn until the bulb is hermetically sealed. Then, while still exhausting, the glass tube, d, is hermetically sealed in the flame. When cooled the sealed tube, d, is set in a concentrated solution of pyrogallic acid, the seal is broken, and when the pyrogallol solution reaches n, tube d is again hermetically sealed.

Vottelier's method.—Prepare about four culture tubes in the ordinary way, using solid media, when inoculated close them with loose cotton plugs which are pushed well down into the tubes. Pour 50 cubic centimeters of an alkaline solution of pyrogallic acid into a common glass beaker. Cover the pyrogallol with a layer of liquid paraffin 2 centimeters deep. Invert the culture tubes into this beaker. Introduce hydrogen into each tube for about five minutes, then place the apparatus in the incubator. In addition, this writer pours on top of the liquid paraffin a layer of the following mixture: Paraffin, solid, 50 parts; cera flava, 20 parts; vaseline, 30 parts. According to Vottelier this makes an absolutely air-tight seal. The author recommends the use of large test tubes for this purpose, as in case of small test tubes the slanted agar slides down easily. The agar must be well cooked before slanting. Before inoculation the condensation water is carefully poured off and a loose, sterile cotton plug is inserted; an occasional infection is made harmless by the pyrogallic acid.

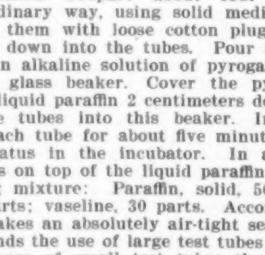


Fig. 53.

Upon concluding this review the author's attention was drawn to a few appliances and methods not described herein. Their inventors are: Zettnow (1894), Migula (1895), Klein (1898), Epstein (1898), Bombicci (1902), and Turro (1902). These apparatus differ but slightly from those already discussed, and the methods are all based upon the principles treated in the review. Space does not permit here a detailed description of same, but the references are given in the bibliography.

CLASSIFICATION OF THE METHODS REVIEWED ACCORDING TO THE PURPOSE FOR WHICH THEY ARE MOST ADAPTED.

The inventors of the existing methods and apparatus for the cultivation of anaërobic bacteria devised their apparatus and introduced their methods for certain specific purposes. While one set of apparatus may give perfect satisfaction in one line of work, it may be almost worthless elsewhere. This fact is in perfect accordance with the strong tendency for the division of labor and occupation which has so completely revolutionized the economic, industrial and scientific world of the past century. The study of anaërobic bacteria involves a series of experiments, the different stages of which vary in character. And in order to obtain rapid and satisfactory results, it is necessary that the methods employed for this work should be chosen in accordance with the purpose of their respective inventors. With the endeavor, then, of facilitating the proper selection of methods the following classification has been made:

1. Methods for the determination of the presence of anaerobic bacteria in a given substance.
2. Methods for isolating anaerobic bacteria.
3. Methods for growing pure cultures of anaerobes on different media.
4. Methods for the propagation of pure cultures and for the preservation of stock cultures.
5. Methods for the preparation of toxins.

1. *Methods for the determination of the presence of anaerobic bacteria.*

The simplest and most practical methods for the study of the relation of bacteria to free oxygen consist of cultures in deep layers of solid medium as recommended by Liborius (V. a.), the use of Smith's fermentation tube (V. f.) (Fig. 50) and the use of Wright's apparatus (V. e. Figs. 46 and 47).

2. *Methods for isolating anaerobic bacteria.*

To this class belong most of the methods that permit the use of solid media. In laboratories where apparatus like that of Novy (II, Fig. 24), Gabinsky (II, Fig. 23), and others are within reach, the use of plate cultures in hydrogen atmosphere is most satisfactory. In the absence of large apparatus cultures in deep layers (V. a.), Esmarch roll cultures for anaerobic bacteria as recommended by Esmarch and Schill (V. a.), Buchner's method (III, Fig. 30) are of value.

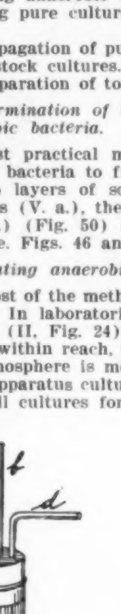


Fig. 54.

3. *Methods for growing pure cultures of anaërobic bacteria on different media.*

As in the study of aerobic, so also in that of anaerobic cultures the species can be determined only by their cultural characteristics. For the determination and differentiation of species it becomes necessary, therefore, to use various kinds of special media, and as it is of great importance, if accurate and reliable results shall be obtained, that the temperature and atmospheric conditions under which the cultures are made should be as uniform as possible, it is obvious that large apparatus, such as Gabinsky's especially, which will permit a large number of culture tubes simultaneously, are most adapted for this work.

4. *Methods for the propagation of pure cultures and the preservation of stock cultures.*

Where it is desirable to have on hand cultures, fluid or solid, of anaerobic species for the study of morphological and physiological characters, it is necessary to use methods that are simple, permit prolonged growth of the organisms, and from which culture material may be obtained without difficulty. As valuable methods for this purpose may be named Smith's fermentation tube containing ordinary peptonized bouillon and small sterile pieces from internal organs of rabbits, guinea-pigs, pigeons, etc. (V. f.), Wright's tube (V. e., Figs. 46 and 47), or Liborius' method (V. a.). For stock cultures of anaerobic bacteria Liborius' deep layers (V. a.) are most satisfactory.

5. *Methods for the preparation of toxins.*

Where anaerobic bacteria are cultivated for the purpose of extracting toxins from the culture medium, apparatus that permit liquid cultures in large quantities can only be considered. For this purpose Kasparec's apparatus (V. c., Fig. 39) will serve, Park's modification of same (V. c.) and the two apparatus invented by Smith (V. f., Figs. 51 and 52).

NUTRIENT MEDIUM.

While, generally speaking, most of the nutrient media prepared for the cultivation of aerobic bacteria will also serve, and are constantly used for anaerobic cultures, experience has shown that the latter are

more exacting in their requirements of favorable media. It is not the author's intention to enter into a detailed discussion of the preparation of the media, as such instruction can be obtained from text-books and laboratory directions in bacteriology. What applies to aerobic species, will also hold true for the anaerobes. It is impossible to give a hard-and-fast rule, which embraces the media adapted for anaerobic bacteria as a group. Individual species may have their individual peculiarities which call for special media or media which have proved to be most favorable for their growth. On the other hand, it is deemed of value to draw the reader's attention to a few of the most important factors, in which the requirements of anaerobic bacteria seem to differ from those of the aerobes.

1. *Composition of Medium.*

Little need be said here as the composition of media has already been discussed in chapter iv. on the reduction of oxygen; the same chapter contains a summary of the composition of media, which Novy (1893) found to be especially adapted for anaerobic cultures. This author, who has made a careful study of the ingredients of nutrient media that are most suited for anaerobic development, shows that the addition of peptone greatly favors anaerobic growth. Bouillon without peptone proved to be a very poor medium, the addition of one per cent peptone very materially improved it, and the maximum effect was reached with bouillon containing two per cent peptone. Any addition above two per cent did not have any noticeable effect on, or lowered the power of nutrition of such a medium. The same author also highly recommends the addition of small amounts of litmus to the nutrient medium.

Smith (1899) adds small sterile pieces of internal organs of rabbits, guinea-pigs, etc., to ordinary sterile bouillon in fermentation tubes, and successfully uses these tubes for anaerobic cultures without resterilizing the bouillon. In this way the medium contains some albumin in solution, and therefore offers favorable conditions for bacterial growth. (For method see V. f., Smith, 1899.)

As regards the action of sugars and other reducing agents, the reader is referred to IV.

2. *Reaction of Medium.*

Most of the scientists, who have studied anaerobic bacteria, agree that this group of organisms generally requires a medium with a slightly alkaline reaction. Kitasato observed that the bacillus of Rauschbrand grows best in a slightly acid medium. According to Novy, 1893, anaerobic bacteria thrive well in strongly alkaline bouillon, but in such cultures their vitality decreases rapidly and the organisms die in a comparatively short time. Thus, Bacillus œdematis maligni No. 2 died within two days after inoculation, although it showed very vigorous growth at the start.

3. *Age of Medium.*

Since it is of great importance, if good results are to be obtained, that the medium should be as nearly free from oxygen as possible, it is obvious that old media are not suited for anaerobic cultures. The older the medium, the longer has been the time during which the latter has been absorbing oxygen from the air. It is, therefore, necessary that, for anaerobic cultures, fresh media be used. Novy (1893) Hammerl (1901) and other investigators found that in a given series of bouillon cultures the anaerobes developed much more vigorously in freshly made than in stale medium. If stale bouillon is used it should be reboiled for the purpose of driving out the oxygen present, before the medium is inoculated. The same holds true in the case of agar, while gelatin tubes evidently do not require this precaution. Thus Novy was able to cultivate anaerobic bacteria in gelatin that was six months old just as readily as in freshly made gelatin.

4. *Age and Quantity of the Inoculating Material.*

a. Age. Novy (1893), in a series of experiments with bouillon cultures of ages ranging from one day to four months, observed that where old cultures are used as inoculating material generally negative results are obtained, while, where he made the inoculations with young cultures, no difficulty was encountered in obtaining vigorous growth. He therefore concludes that the failure to secure the desired growth is often due to the age of the culture used.

b. Quantity. For the successful cultivation of anaerobic bacteria it is generally advisable and necessary to use large quantities of inoculating material in order to start growth. Hence, where inoculations with small amounts of culture material have proved unsuccessful, positive results may be obtained by using larger amounts of it. After the bacteria have begun to grow there is little difficulty in continuing their development.

TRADE SUGGESTIONS FROM UNITED STATES CONSULS.

Provisions for Carrying Out German Meat Inspection.—Under date of August 25, 1902, the secretary of embassy at Berlin, Mr. J. B. Jackson, sends a clipping from the North German Gazette of the 24th instant, containing an article in regard to the provisions for carrying out the meat inspection laws. A translation of the article, prepared by Mr. Richardson, third secretary of the embassy, is given below:

The competent ministers sent on the 1st of August of this year a detailed order to all the so-called "Ober" and "Regierung," or government presidents, intended to prepare the carrying out of the bill (law) regarding the cattle and meat inspection of June 3, 1900, which takes effect on April 1, 1903, and of the Prussian special bill (law) of June 28, 1902, in connection with the above bill (law) of the empire. The order discusses in two parts the measures which are to be immediately taken in regard to the inspection and sanitary treatment of the meat imported within the custom boundary, as well as that of the cattle and meat when slaughtered in the interior.

The first paragraph in connection with a temporary order sent by the Finance Minister to the provincial boards of customs and taxes on the 17th of May deals with the principles for the institution and equipment of the offices which are to be opened for the inspection of foreign meat according to the resolution of the Bundesrath. Fifty-six offices of the kind are counted for Prussia, 29 of which are intended for the inland and imported meat, whereas the remaining 27 are only intended for the inland. Besides the 56 above-mentioned offices there are 17 custom offices merely for importation without inspection. The meat going through these 17 custom offices is to be sent to one of the offices of inspection, where it is to be inspected. The kind of equipment of each of the offices, especially the number and selection of the offices required, as well as the space and buildings, depends in the first place on the quantity and quality of the meat which is likely to be inspected in the same office. The boards, therefore, have been ordered first to carefully estimate the extent of the importation of meat which is intended for inspection by each office, and this will be no easy task, on account of the alterations and changes of the meat importation which are possible on account of the carrying out of the meat inspection at the frontier.

According to the division of the inspection required by the orders of the Bundesrath into three parts, there are (1) a veterinary inspection of all the fresh and prepared meat with the exception of the fat, (2) a microscopical inspection of fresh and prepared pork, and (3) a chemical inspection of prepared meat and fat. The personnel of the inspection is to be composed of approved animal doctors (veterinary surgeons), of civilians who have been trained for the inspection of pork, and, finally, of chemical experts.

The order contains detailed arrangements as to what way and on what conditions this personnel is to be selected and engaged according to the above-mentioned estimates of the presumptive qualities of inspection meat, with a view to the laws of examination given by the Bundesrath for trained meat inspectors and to the organization of the boards of approbation.

In order to give the officers of the inspection an opportunity of practising, in many cases special accommodations or other arrangements will be necessary at the offices; for instance, separated laboratories for the veterinary experts for the finer microscopical or bacteriological investigations; then rooms for the pork inspectors will be necessary; and, finally, chemical laboratories will be required if the local conditions of the place do not permit to have the proofs of meat and fat intended for chemical inspection inspected in other laboratories of chemists residing at the place. The boards have been ordered to make an estimate of the extent, place and expenses of these accommodations.

Finally, propositions are to be made to the government, whether and to what extent it is necessary to allow the alleviations for the smaller importations of meat, which can be given by the governments of the respective States according to paragraph 14, part 2, of the imperial bill (law).

In the second part of the order the new laws are compiled in a concise way from which the extent of the inland meat inspection may be seen, which is to be introduced on the 1st of April, 1903, or, if already existing, is to be subjected to these laws. Then the formation of the inspection districts is discussed as well as the training and engaging of the necessary personnel of the experts (exclusive competency of approved veterinary doctors, aptness and training of civilians, especially the organization of the boards of examination and execution of the transitory orders) and in a special subsection the way in which the pork inspection is to be inserted into the general future meat inspection. The boards are particularly desired not to raise the difficulties of the introduction of the general meat inspection by making considerable changes in the organization of the pork inspection which already exists in Prussia to an extent of 95 per cent, but to try and remove the faults of this branch of the inspection by gradually training its personnel in a better way and, above all, by a strict control of the meat inspection by experts.

The boards are further directed to collect and to send in the material respecting the costs of the inspection; the manner of fixing and raising them; the arrangements for selling meat by auction; the competency of the respective boards for carrying out the orders of the police with regard to the meat inspection; the way of making complaints against it, and the control of the meat inspectors.

The boards are required to send in the reports within two months, which is not very much time considering the great number of questions to be answered. Only on the base of these reports will the respective ministers be in a position to give definite directions for carrying out the bill in a way according to the different local conditions of the place of inspection. At any rate, it is to be seen from the above sketch, in which not the whole number of the matters to be settled is discussed, that the efforts of all the magistrates and boards connected with the meat inspection will be necessary in order to bring about by April 1, 1903, the day when the bill goes into effect, the vast apparatus required for the meat inspection put into working order everywhere without too great difficulties.

Openings for Steel and Iron in Greece.—Inquiries have recently been made at this consulate concerning the possibility of importing American wire for the manufacture of wire nails. Before bringing the matter to the attention of United States manufacturers, I have taken occasion to inquire into the possibilities of such a trade in this section, and I find (1) that the market is sufficiently active to merit attention, and (2) that it is wholly dependent upon Europe for its supply of the raw material.

The annual importation of steel wire into this district is about 2,000 tons, arriving principally during two months of the year—April and May—at which time there is extraordinary activity in the manufacture of boxes and barrels, for the opening of the current trade in August of each year. Belgium gets the largest share of this trade, although Germany and Servia are participators to an extent, the average price at which these countries export this wire being 20 francs ($3.86) per 100 kilogrammes (220.46 pounds). In this city there are three nail factories; in Piræus, three, and in Volo, one. Since these inquiries have come from importers interested in keeping the local factories supplied, it may be supposed that they have been investigating conditions in the light of direct transportation, which this port now enjoys with New York, and that there is some ground for believing that wire may be imported from America to advantage.

There is also, I am told, a market for iron girders and beams for building purposes, bridges, etc., to the extent of 6,000 tons or more annually. Practically, the whole of this trade is controlled at present by Belgium, which has also been supplying large quantities of steel rails and construction iron for the extension of the Peloponnesus Railroad to Calamata.

Since no favored-nation clause covers the importation of these materials—both steel wire and iron being on the free list—there is nothing to keep our manufacturers from competing for what trade there is, except prices and terms of sale. The latter will probably form the stumbling block rather than the former, since it is well known that our exporters are not generally disposed to give the easy terms which European countries continually grant. Four months' time is usually asked, or a discount of 3 per cent.

It is altogether probable that the verdict of our exporters will be that the Greek market for such goods is too small to warrant immediate attention. Its smallness will be admitted; at best, not more than two cargoes of these products could be marketed in the Peloponnesus during any one year. However, it is probably true that our principal gains or losses in exportation may be traced to the degree of care with which we have looked after the smaller orders, rather than to the success or failure of greater ventures. Our trade with foreign countries has generally been built up from comparatively humble beginnings. Our ability to successfully compete for great contracts has been demonstrated in the markets of the world, but it may also be worth while to give attention to smaller demands. It holds true between nations, as between individuals, that when satisfaction has been given in one line of trade, there exists a disposition to turn to the same market for other needs. Greece has been buying a few commodities from the United States; if her people wish to see what else we have for sale, however small the demand may be, it will be better to show our goods. I should like to see our manufacturers supply the needs which I have here outlined. Those who are disposed to try for the trade can obtain particulars not herein mentioned, as well as the names of inquirers, by applying to this consulate.—Frank W. Jackson, Consul at Patras.

Custom House in Yucatan.—Consul W. W. Canada reports from Veracruz, September 2, 1902:

The custom house heretofore located at Puerto Morelos has been removed to "La Bahia de la Ascension," both places on the east coast of Yucatan, where it was opened August 1, 1902. At Cozumel, on the island of Cozumel, a branch of the above-mentioned custom house was also established on the same date. The jurisdiction of the custom house at Progreso has been extended to a point situated at 87 deg. 32 sec. longitude west of Greenwich, on the north coast of the peninsula of Yucatan. From this point to Cape Kuche, the district is under the jurisdiction of the custom house at Bahia de la Ascension, and the rest of the east coast is under the jurisdiction of the custom house of Chetumal.

Branch of the Ussuri Railroad.—Commercial Agent R. T. Greener, of Vladivostock, July 26, 1902, says:

An extensive region east of Vladivostock, hitherto inaccessible, is to be placed in communication with the south Ussurian territory by a branch from the Ussuri Railroad. It will be a wide-gage road, and is estimated to cost about $100,000. It will probably be begun this year. During the winter months timber can be obtained cheaper and work is paid for at lower rates.

Pressed Steel Cars in Germany.—Under date of September 1, 1902, Consul B. H. Warner, of Leipzig, says:

The directors of the Prussian State railroads have recommended to the Minister of Public Works that a bill be introduced into the Prussian Parliament, providing for the construction of pressed steel coal cars of 20 tons carrying capacity. The minister, after giving the matter careful consideration, has suggested that the proposals be somewhat modified, and, as soon as the bill is amended, it is believed that Prussian State railroads will place pressed steel cars in commission.

Transit Dues on Suez Canal Diminished.—Under date of September 4, 1902, the Department is informed by Ambassador Horace Porter, of Paris, that, according to a note received from the president of the Suez Canal Company, on and after January 15, 1903, the rate of transit through the canal will be diminished 50 centimes (9.6 cents) a ton.

Index to Advance Sheets of Consular Reports.

The Reports marked with an asterisk (*) will be published in the Scientific American Supplement. Interested parties can obtain the other Reports by application to Bureau of Foreign Commerce, Department of State, Washington, D. C., and we suggest immediate application before the supply is exhausted.

SELECTED FORMULÆ.

Toilet Preparations.—While absorbent powders and toilet waters are in request all the year around there is more need of the former in the warmer part of the year than in cool weather and toilet waters proper come within the latter category. And the pharmacist should now keep himself well provided with both.

By toilet waters proper we mean perfumed liquids designed more especially as refreshing applications to the person—accessories to the bath and to the operations of the barber. They are used sparingly on the handkerchief also, but should not be of so persistent a character as the "extracts" commonly used for that purpose, as they would then be unsuitable as lotions.

A most excellent preparation of this kind is produced by the following formula, which was originally published by Piesse:

Cologne Water No. 1.

Oil of neroli	6 drachms
Oil of rosemary	3 drachms
Oil of bergamot	3 drachms
Oil of cedrat	7 drachms
Oil of orange peel	7 drachms
Deodorized alcohol	1 gallon

This preparation unfortunately is somewhat expensive, but people who can afford to pay will frequently choose it in preference to other kinds. Where price is an objection, the following may be offered. Its odor is a passable imitation of that produced by the first formula:

Cologne Water No. 2.

Oil of lavender	½ ounce
Oil of rosemary	½ ounce
Oil of bergamot	1 ounce
Oil of lemon	2 ounces
Oil of clove	½ drachm
Deodorized alcohol	1 gallon

To secure a satisfactory product from the foregoing formulas it is necessary to look carefully to the quality of the citrine oils; oil of lemon, as is well known, is prone to change, and oil of orange peel is especially susceptible. If exposed to the atmosphere for a short time, it becomes worthless, and will spoil the other materials.

Another quite popular perfume of this class is lavender water. It may be made by the following formulas:

Lavender Water.

I.

Oil of lavender	4 ounces
Deodorized alcohol	6 pints

II.

Oil of lavender	4 ounces
Rose water	1 pint
Deodorized alcohol	6 pints
Magnesium carbonate	1 ounce

Triturate the oils with the carbonate, gradually adding the water and alcohol, previously mixed, and filter.

Rose Lavender.

Oil of lavender	4 ounces
Oil of rose	2½ drachms
Deodorized alcohol	7 pints

The English oil of lavender is much better than any other kind; a difference apparently due to the modifying effect of the moist climate of the country. Its high cost, however, renders the use of other kinds necessary in most cases. The oil from the flowers should be preferably taken in the latter case.

Violet Water.

I.

Violet essence	4 ounces
Cassie essence	1 ounce
Orris tincture (8 ozs. to 1 pt.)	1 ounce
Ambergris tincture (1 dr. to 1 pt.)	½ ounce
Deodorized alcohol	1 pint

II.

Violet essence	4 ounces
Cassie essence	1 ounce
Rose essence	3 drachms
Orris tincture	1 ounce
Ambergris tincture	2 drachms
Bitter almond spirit (5 ozs. oil to 1 oz. alc.)	20 minims
Deodorized alcohol	1½ pint

III.

Cassie essence	2 ounces
Rose essence	1 ounce
Tuberose essence	1 ounce
Orris tincture	1 ounce
Ambergris tincture	1 ounce
Bitter almond spirit	20 minims
Deodorized alcohol	1 pint

IV.

Orris tincture	5 ounces
Jasmine essence	2 ounces
Cassie essence	1 ounce
Vanilla tincture (6 dr. to 1 pt.)	1 ounce
Deodorized alcohol	1½ pints

The tinctures directed in these formulas are all to be made with strong alcohol. The materials are macerated a week or more, filtered and sufficient menstruum added through the filter to bring the finished preparations to the measure of the menstruum originally taken.

The flower essences directed are those made from No. 24 pomades, the number indicating the strength.

V.

Rose essence	4 ounces
Cassie essence	5 ounces
Jasmine essence	4 ounces
Tincture of orris root (1 to 4)	5 ounces
Tincture of vanilla (1 to 16)	2 ounces
Oil of bergamot	1 ounce
Spirit of ionone (1 to 20)	½ ounce
Deodorized alcohol	1 quart

—Drug. Circ. and Chem. Gaz.

(To be continued.)

THE

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